Innovations in Science Education and Technology

Technology, Science Teaching, and Literacy

A Century of Growth

Kenneth P. King

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Kenneth P. King
Northern Illinois University
DeKalb, Illinois

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To Tina, Marshall, and Harrison

For patience, support, and love

Preface to the Series

The mandate to expand and improve science education is an educational imperative and an enormous challenge. Implementing change, however, is complicated given that science as well as science eduation is dynamic, continually incorporating new ideas, practices, and procedures. Science and science education take place in varying contexts and must deal with amazingly rapid technological advances. Lacking clear paths for improvement, we can and should learn from the results of all types of science education, traditional as well as experimental. Successful reform of science education requires careful orchestration of a number of factors which take into account technological developments, cognitive development, societal impacts and relationships, organizational issues, impacts of standards and assessment, teacher preparation and enhancement, as well as advances in the scientific disciplines themselves. Understanding and dealing with such a complex mission is the focus of this book series. Each book in this series deals in depth with one or more of potential factors for understanding, creating and sustaining effective science education reform.

In 1992, a multidisciplinary forum was launched for sharing the perspectives and research findings of the widest possible community of people involved in addressing the challenge of science education reform. Those who had something to share regarding impacts on science education were invited to contribute. This forum was the *Journal of Science Education and Technology.* Since the inception of the journal, many articles have highlighted relevant themes and topics and expanded the context of understanding to include historical, current, and future perspectives in an increasingly global context. Recurring topics and themes have emerged as foci requiring expanded treatment and presentation. This book series, "Innovations in Science and Technology," is the result.

It is a privilege to be able to continue to elucidate and effect improvement and reform in science education by providing this in-depth forum for the work of others. The series brings focus and understanding to efforts worldwide, helping readers to understand, to incorporate, and to utilize what we know, what we are

learning, and what we are inventing technologically to advance the mission of science education reform worldwide.

Karen C. Cohen
Cambridge, Massachusetts

Preface

This book deals with the use of technology in science teaching. The author is not, nor has ever had an intention of being a "techie." Rather, I spent the first decade of my professional life as a high school physics teacher, making occasional uses of technology to further student understanding and to automate my own teaching practices.

During my graduate work, my interest in the use of technology continued. Catalyzed, to some extent by the increasing availability of graphical interfaces for computers, the realization struck that the computer was more and more becoming a tool that all teachers could use to support their teaching practice—not simply those with a passion for the technology itself. The rapid changes in the hardware and software available, however, frequently caused me to reflect on the usefulness of technology—if it were to change at such a rapid pace, would anyone, save for those who diligently focused on the development of these tools, be able to effectively use technology in science teaching? Was change to rapid to yield a useful tool for teachers?

To address this interest, I examined the nature of science teaching during this century—using the equally fluid notion of "scientific literacy"—which formed the organizing principle for this study. The result is a examination of how technology was used to accomplishing this goal of producing scientifically literate citizens. What was observed is that technology, indeed, consistently came to the service of teachers as they attempted to achieve this goal.

One area that this study did not well address was what might be called the “misuse” of technology in teaching science. The unfortunate notion that the perfect instructional video lasts 48 minutes—to fit perfectly into a 50-minute class period—unsurprisingly was not represented in the literature. Recognizing that this takes place on occasion perhaps underscored the need for a study of this sort—to profile examples of the best uses of technology for science teaching, rather than the occasional misuses. I hope that in some manner my work here has addressed that goal.

Chapter 1 sets the stage for the study, describing the delimitations and scope of the investigation. Chapter 2 traces the evolution of the term scientific literacy from early in the twentieth century to the final decade. Chapter 3 examines the role of the motion picture in science instruction. Chapter 4 investigates the role of the radio in science instruction, and Chapter 5 focuses on the role television has played in science instruction. Chapter 6 covers the instructional uses of the computer, and Chapter 7 reflects on the role of these technologies in science instruction and considers possible directions for the use of technology in science education in the decades to come.

Acknowledgements

A number of individuals deserve recognition for making this book a reality. First and foremost, to members of my dissertation committee, who helped shape the original version of this study from a hazy idea into a workable and worthwhile product. To Professors Thomas Thompson, David Ripley, and James Lockard, I owe a tremendous debt of gratitude.

Dr. Thompson's knowledge of science education is estimable, and his insights provided the essential role of developing a broad perspective that was meaningful to the needs of science education and science educators. Dr. Lockard's extensive knowledge of instructional technology provided the second key component of the study. With his in-depth knowledge of the essential issues of teaching and learning with technology, he ensured a high degree of technical accuracy and his insights into the evolution of technology proved essential. Dr. Ripley, as the historian, ensured that a balanced message was delivered, helping me to present the most accurate view of events that I could deliver. Appreciation must be extended to Dr. Norman Stahl, Curriculum and Instruction Department Chairman, who suggested that a historical study might be of interest. That suggestion was the catalyst that moved the study ahead rapidly.

Additional recognition must be offered to Dr. Karen Cohen, editor of the Journal of Science Education and Technology, as well as this series of books dealing with issues in science education. Her suggestion that the articles I had published in the Journal of Science Education and Technology was the encouragement I needed to make this work a reality.

At Iowa State University, Becky S. Jordan and Jim Wilcox of the Iowa State University Archives offered excellent help and access to the early station records and programs broadcast through WOI-TV.

Thanks and appreciation are extended to Kluwer Academic Publications for permission to use the material reprinted in Chapters 3 and 5. They appeared earlier in slightly altered form in the Journal of Science Education and Technology (September 1999 and September 2000, respectively).

Contents

Chapter 1

Introduction

> If there is a single word that is commonly associated with educational technology, it is "promise.".... Advocates of particular educational technologies such as educational radio, motion pictures, television, video cassettes, video discs, and computers have lauded the potential of their particular favorites as promising a revolution in education. (Levin and Meister 1985, p.1)

In the statement above, Levin and Meister began their examination of the disappointments associated with technologies over the decades. They found many areas in which to affix blame as to why technology had not accomplished its promised goals of revolutionizing teaching. Rather than focus on the sometimes giddy and often inflated promises of what technology was supposed to bring to teaching, this study will focus on successful classroom practices using technology in science education. They were not promises; rather, they represented efforts by teachers to make use of new and innovative tools to help students learn.

A study such as this has been long overdue. The symbiotic nature of science education and technology has led to many individuals using technological tools to improve teaching and learning. Placing these tools into a broader historical context will help future educators look more objectively at the use of technology in the classroom, by offering perspective on its antecedents.

Interest in using technology to "improve" teaching is as great now as it has ever been. National initiatives supporting the infusion of technology in instruction include federal legislation such as Goals 2000 and Secretary of Education Richard Riley's (1997) goal that students should be entitled "to

have their classroom connected to the Internet by the year 2000 and to be technologically literate." To this end, school districts sponsored "net days" and provided funds for technology and teacher training in its use.

Effective teachers use a variety of tools. Technology though the decades has represented a tool which provided teachers numerous opportunities. As defined by Reynolds and Barba (1997), technology is "electronic related devices and products of the production of these products such as the computer" (p. 262). With these tools, teachers were given the means to both automate and innovate their classroom practices. Whether seeking to achieve Thomas Edison's goal of one hundred percent efficiency in instruction or simply to develop a more sophisticated set of thinking skills, teachers found innovative uses for technology throughout the century.

Support for the use of technology emerged from all levels, including professional organizations such as the National Science Teachers Association (NSTA). The NSTA in 1998 stated:

> NSTA recognizes and encourages the development of sustained links between the informal institutions and schools. Informal education generally refers to programs and experiences developed outside of the classroom by institutions and organizations that include...media [such as] film, broadcast, and electronic. ("An NSTA Position," p. 54)

The use of technology ranged from the informal as described above--students watching television programs such as <u>Bill Nye the Science Guy</u> or <u>NOVA</u>--to highly structured approaches such as Optical Data's <u>Windows on Science</u> videodisc series. In between were software programs that allowed and encouraged exploration by students, using the World Wide Web as a source of information and as a means of communication, and using software to create a presentation of their experimental results.

Connecting the use of these tools with the past and current ideas of scientific literacy provided the overall structure for this study as to what science education was all about. Scientific literacy represented a concept that evolved over the decades. In essence, it represented the purpose to which science teaching was to be dedicated. Over the decades it moved from primarily a content focus to a broader set of ideas which included also the thinking skills and goals for learning science in a way that would positively impact society for all its members.

To the reader with an interest in some of the curriculum movements of the late 1980s, this study recognized the contributions of the science-

technology-society (STS) structure for science education. However, it does not focus on STS except to place it in the broader context of some of the primary curriculum issues of the 1980s and 1990s. STS regarded technology primarily as a philosophy and design process rather than as a set of tools.

Scientific literacy represented the "why" of this study. Representing the "how" are the technological tools used to achieve goals in scientific literacy. In particular, the focus will be directed toward the use of three technologies and their roles in science education: the motion picture, the television, and the computer. While other technologies have been helpful in the process of science teaching, these three are still, in one fashion or another, still available for purchase. Each of these technologies was lauded as "solutions" to the problems faced by education; each offered many of the same promises for improved teaching and learning; and each was subsequently criticized for not living up to its promises. Following their evolution to the current practices in the 1990s affords the opportunity to see how the same tools were used during different conceptions of scientific literacy.

What also emerged from this study were general findings with respect to the use of technology in science teaching, the trends associated with the use of technology in the science classroom, the ones unique to each technology, and the broader trends present among all three of them. In addition, how these trends impacted teaching practice and advanced the purposes of science education were examined.

Finally, the last purpose of this study was to provide a broader historical perspective for the use of technology in science teaching during the twentieth century and to offer suggestions for additional study. Examining the technologies of the past and examining why their potential was not met can provide insights into better use of technology in the future.

The need for this study is related to the purpose identified previously. With the ever-increasing clamor encouraging the use of technology in the nation's science classrooms, the utility of a historical study is clear. By placing contemporary uses of technology into a broader context, the current and anticipated uses of technology may more clearly be ascertained. Technologies that may be "mature" in terms of their theoretical use may be suffering from the struggles related to the early stages of implementation for some individual teachers and schools.

The goal of this study is to provide a comprehensive overview of how the motion picture, radio, television, and the computer have been used to support

the goals of science teaching. If a future reader is able to perceive his or her use of technology as part of a broader canvas, then the goals of this investigation have been met.

Limitation of the study to four media was necessary due to the large array of possible technologies in current and past use in the science classroom. Each of the technologies examined during the course of this study remains in use in one form or another. Other technologies, such as the overhead, have no applications unique to science teaching such as the motion picture, radio, the television, and the computer provide. Finally, a comprehensive body of literature describing their use from their inception is available. Some technologies such as the overhead projector and the slide projector were veritable ciphers within the science education literature. These technologies remain for future investigators.

As part of the methodology, numerous representative software applications, television programs radio broadcasts, and motion pictures were described. Examples of these pieces of software were examined during the narrative to show representative classroom applications of technology.

Before examining the motion picture, radio, television, and the computer, an audit of the various incarnations of scientific literacy is appropriate. This examination begins in the early part of the twentieth century, with the role of the Nature Study movement in elementary education and the position described in the Cardinal Principles of Secondary Education, which dominated the discussion in science education.

Chapter 2

Science Education

Achieving Scientific Literacy

With these words, one of this century's best-publicized educational manifestos mapped out key areas of concern (National Commission on Excellence in Education, 1983):

> If an unfriendly foreign power had attempted to impose upon America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed it to happen to ourselves. We have even squandered the gains in student achievement made in the wake of the Sputnik challenge. Moreover, we have dismantled essential support systems that helped make those gains possible. We have, in effect, been committing an act of unthinking, unilateral educational disarmament. (p. 5.)*

The gauntlet had been thrown down. Education must change. Standards must be higher. Students must work harder and smarter. While the previous quote is perhaps among the more inflammatory in the rhetoric of educational reform, the intentions it reflects are not.

In this chapter is included a capsule history of three issues: the evolving issue of what constituted scientific literacy, the practice of science education (K-12), and the reform projects and policy statements that impacted the domain of science education. An understanding of these three trends helps to inform an examination of how technology was used in the practice of

* While the effects of A Nation at Risk were significant in terms of public perception and policy issues, Berliner and Biddle (1995) in The Manufactured Crisis made a convincing case that creation of A Nation at Risk and related documents badly misrepresented the actual status and quality of American education.

science education as a means of enhancing the scientific literacy of students during this century.

1. SCIENTIFIC LITERACY

Science education can, in one form or another, trace its roots back to the ancient Greeks. The intent of this study was to examine the use of specific modern technologies in the practice of science teaching, so the study began in the early years of the twentieth century.

The strand that ultimately united the historical overview was the issue of scientific literacy. Though the term "scientific literacy" was coined only in the 1950s, the concept of scientific literacy can be observed as early as the National Society for the Study of Education (NSSE) Thirty-first Yearbook during the early 1930s (Bybee, 1997). The idea of what constituted a proper scientific education was connected to the idea of creating "educated laymen." (National Society for the Study of Education, 1932, p. 133) The introduction of the contemporary use of the term "science (or scientific) literacy" was credited to Paul DeHart Hurd in 1958. In his essay, "Science Literacy: Its Meaning for American Schools," Hurd made several points which are still valid today.

> More than a casual acquaintance with scientific forces and phenomena is essential for effective citizenship today. Science instruction can no longer be regarded as an intellectual luxury for the select few. If education is regarded as a sharing of the experiences of the culture, then science must have a significant place in the modern curriculum from the first through the twelfth grade. (p. 13)*

After the need for science in the curriculum was identified--as a tool for all citizens, not merely an intellectual elite—Hurd addressed other concerns related to the issue:

> Today most aspects of human welfare and social progress are in some manner influenced by scientific and technological innovations. In turn scientific knowledge establishes new perspectives for reflection upon social problems. The ramifications of science are such that they can no longer be considered apart from the humanities and the social studies. Modern education has the task of developing an approach to the problems that mankind considers science, the humanities, and the social

* This article represented the first articulation of the modern (1980-1990s) definition of "scientific literacy."

> studies in a manner so that each discipline will complement each other. (p. 16)

Clearly, Hurd's prescience laid the groundwork for the advocates of later movements including Science-Technology-Society (STS), Project 2061, and National Science Education Standards. His article has more in common with essays written during the 1980s and 1990s regarding policy and curriculum than with his contemporaries who were focused on specific science curricula. As defined by the National Research Council (1996),

> Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity. (p. 22)

The American Association for the Advancement of Science (1993) offered a similar description of scientific literacy:

> Use the habits of mind and knowledge of science, mathematics, and technology they [students] have acquired to think about and makes sense of many of the ideas, claims, and events that they encounter in everyday life. (p. 322)

Extending this into action was the claim that

> Science literacy enhances the ability of a person to observe events perceptively, reflect on them thoughtfully, and comprehend explanations offered for them. In addition, those internal perceptions and reflections can provide the person with a basis for making decisions and taking action. (AAAS, 1993, p. 322)

This view of scientific literacy moved beyond the view common to the early 1960s in which one of the key purposes of science in the schools was to create a new generation of scientists. The view advocated by Hurd and now generally accepted is that the purpose of scientific literacy is to create a more effective, better-functioning citizen.

The issue of scientific literacy has been a defining issue of science education. Even in the early days of science education, the idea of creating productive and engaged citizens was a goal of the curriculum. Current efforts have defined the characteristics of scientific literacy more deliberately, but the same underlying goals of an engaged, thoughtful, and reflective citizenry have been present throughout the century.

The use of technology in science education can be seen as a means of accomplishing scientific literacy goals. Whether addressing the scientific literacy concerns appropriate to the Nature Study movement or the more contemporary issues related to STS curricula, technology has invariably found a place as a tool of the educator. In the following chapters, an investigation of technologies that have been employed in science teaching are examined. The ultimate goal of instruction, to achieve scientific literacy, provides a means of examining what benefits technology brought to the nation's science classrooms.

Before examining the role of technology, it is helpful to look back briefly at the "state of the practice" in science education during this century. This provides a context in which to examine the various technologies that have found application and influence within the domain of science education.

2. SCIENCE EDUCATION: REFORM DOCUMENTS

Each of the movements in science education practice described previously had its roots in a reform document. These documents assessed the then current practices in science education and provided the direction for future science teaching practice.

2.1 Thirty-first Yearbook

Published in 1932, the NSSE Thirty-first Yearbook was subtitled "A Program for Teaching Science." Its objective was to lay out the curriculum for science teaching for students from kindergarten through college. It was an exceedingly comprehensive document, covering curriculum, instruction, and even the equipment necessary to effectively teach the science curriculum.

2.1.1 Nature Study

In their essay "Ten Myths of Science," Callery and Koritz (1993) identified as one fiction of scientific practice the picture of a lone individual working in isolation on some sort of esoteric project. Science, as with all of the liberal arts, has been informed by society at large and, in turn, has had its influences on society. Science is not, typically, to be practiced in monk-like solitude. The practice of teaching science also has been influenced by societal factors. The trends associated with the teaching of science can be perceived as an expression of larger societal forces. Early in the twentieth

century, the dominant instructional approach in elementary science education was the Nature Study movement. How society and educational practice combined to produce the Nature Study approach provided the starting point for the overview of science education practices.

The Nature Study movement represented the prevalent single strand of practice from circa 1890 until 1920. Though the United States was moving toward an industrial economic base during this time, one still saw the effects of the largely rural population in the foundation principles associated with the Nature Study movement. External to education, frictions in society were exemplified in many ways by the presidential campaigns of William Jennings Bryan, a Midwestern-born politician and advocate of rural America. With this larger background providing an idealization of the rural lifestyle, it was easy to see how educational practices attempted to institutionalize this view.

According to Underhill (1941), Nature Study was considered to be two separate but related conceptual strands.

> First, it may be considered part of a broad and general development resulting from the combined influences of Romanticism and the "new" education. Second it may be thought of more specifically as a school program initiated and largely directed by Dr. Liberty Hyde Bailey and his associates at Cornell University. (pp. 155-156)*

By "new," Underhill was referring to a number of the educational reformers influencing the era, such as Pestalozzi, Rosseau, and Froebel, who conceived the child as functioning and learning

> With an inner urge...acting as a directive force and emphasizing dynamic self-expression, freedom, initiative, and spontaneity. (p. 155)

In one of its most popular expressions, Nature Study in its Bailey incarnation had as one of its principle objectives "making the children so sympathetic with nature that they would enjoy rural life and be happy on the farm." Underhill, 1941, p. 162.) While one of Bailey's goals was to develop sympathies for the rural life and its attendant interactions with nature, the impact of the Cornell program was felt throughout the state of New York and beyond. The essence of this outreach can be seen in agricultural extension services in the Middle West. In Bailey's time, New York, for

* Underhill wrote this book as his doctoral dissertation.

example, free bulletins on nature and agricultural topics were distributed to 25,000 out of the 29,000 certified teachers in the state. (Underhill, 1941)

With this expansion in the number of advocates came additional influence. Nature Study became the standard science practice in the elementary grades. During the decade of the 1890s, the terms "elementary science" and "Nature Study" were considered to be synonyms. By the end of the decade, the student practice of science was exclusively described by the term "Nature Study." According to Underhill, this was intentional: it was a movement by educators of the day to distance themselves from the formalism of then-current practices associated with science teaching.

Apart from the philosophical orientations of the advocates of Nature Study, several principles provided the conceptual basis for the Nature Study approach.

1. Child psychology is distinct from the psychology of adults; this distinction justifies and requires a difference between Nature Study for elementary schools and science for high schools.
2. Nature Study should be primarily observation of common natural objects and practices; the grouping of the facts learned in Nature Study to form principles and generalizations should be reserved for high school and college study.
3. A major value of Nature Study lies in the discipline which it give in habits of thoughtful observation. (NSSE, 1932, p. 17)

Added to these defining principles, Underhill also identified a number of other practices of the prototypical Nature Study curriculum: a tendency towards anthropomorphism, assumptions as to children's interests, a tendency to be text driven, and an almost exclusive focus on the biological sciences.

As a practice becomes institutionalized, it eventually finds itself open to reconsideration and critique. Nature Study was no exception. The points made previously regarding anthropomorphism, questionable applications of psychology, and the intrinsic value of Nature Study were used as ammunition by science educators who disagreed with their very premises. In the Thirty-first Yearbook (NSSE, 1932), the three defining principles were simply rejected out of hand as being "directly in conflict with the teaching of modern psychology and educational theory." (p. 17) Underhill addressed other issues such as that the problems eventually perceived by the approach tended to be both theoretical and practical. While skills such as observation

were a significant part of the Nature Study experience, there was an unfortunate tendency among practitioners to simply have students make observations of text based materials. In addition, much of the text-based material was based on myth, fable, and fairy tale. While these concerns could be dealt with through staff development efforts, the (almost) complete focus on the biological sciences prevented the acquiring of physical science knowledge from the outset.

With the phasing out of the Nature Study approach (it was removed from New York's required list in 1905), the ideas of a more progressive breed of educators came to the fore, dominating many educational practices for the next several decades.

2.1.2 Elementary Science Curriculum

Among the many issues addressed in the Thirty-first Yearbook were problems inherent in the Nature Study approach, which was described as the "traditional science program" for the elementary grades. In particular, these concerns were identified for the Nature Study approach (NSSE, 1932):

> Nature Study, with emphasis on observation, collection, and memorization of names was given a place in the program of elementary science... The extent to which the characteristics of these old theories are still in evidence in the subjects of study included in the curriculum of today is a measure of the extent to which the curriculum is out of harmony with the plan of public education currently accepted. (p. 5)

Additional critiques of the Nature Study approach arose. In large part, the Nature Study movement made extravagant claims for student growth in areas such as the "Ethical, Spiritual, Esthetic, Intellectual, Social, Civic Economic, Vital, Avocation, Vocational, and Practical." (NSSE, 1932, p. 14) The authors of the yearbook regarded as both extravagant and untestable the claim that kindergarten students, through an activity such as feeding squirrels, could realize such goals.

Though the Nature Study approach was becoming less common, its effects were still pervasive. In the textbook Science in the Elementary School (Croxton, 1937), published five years after the recommendations of the Thirty-first Yearbook, topics such as "damage and benefits from insects," "watching animal athletes perform," and "holding a harvest festival" clearly demonstrated the slow pace of change.

Resuming the critique of the Nature Study approach, significant thought was devoted by the authors of the Thirty-first Yearbook, to more appropriate content in the elementary science curriculum. A more appropriate science curriculum went much further than simply addressing the shortcomings of the Nature Study movement (NSSE, 1932).

> In the past, there has been a tendency to restrict the curriculum to the so-called 'fundamentals' or '3 R's.' At present there is a definite trend toward the inclusion of liberal training in the program of studies for the elementary school...The present movement is towards including science as part of this liberal training in universal education. (p. 133)

As a result of this perspective, science education gained an expanded role in the school curriculum.

The dimensions of that new role were developed with this question in mind: "What is the function of science in the lives of educated people?" (NSSE, 1932, p. 134) The answers to that question defined the curriculum and content selected for the elementary school. These areas were defined by three criteria by the NSSE (1932).

> Criterion 1:
>
> Certain objectives that are selected for elementary science should conform to those conceptions (1) that greatly influence the thinking of the individuals who learn their meaning, and (2) that have modified thinking in many fields outside of science. (pp. 134-135)
>
> Criterion 2:
>
> Certain objectives that are selected for science in the elementary school should conform to those goals (information, skills, and habits) in science that are important because of their function in establishing health, economy, and safety in private and public life. (p. 139)
>
> Criterion 3:
>
> Certain objectives that are selected for elementary school science should conform to those facts, principles, generalizations, and hypotheses of science that are essential to the interpretation of natural phenomenon that commonly challenge children. (p. 141)

The three criteria made a broad statement regarding the need for a comprehensive science curriculum in the elementary grades. The content of the curriculum must relate science to society; the content must provide connections among health, safety, and economy (along with the ability to

understand the underlying principles); and the content must provide students with challenging, engaging experiences. These ideas echoed many of the same issues raised by Dewey (1900): that education must be connected with the experiences of the students in society.

> The point I wish to make is that there is abundant opportunity thus given for actual study, for inquiry which results in gaining information. So...the interest of the child in people and their doings is carried on into the larger world of reality. (p. 53)

Stated more succinctly (Dewey, 1916):

> The problem of an educational use of science is then to create intelligence pregnant with belief in the possibility of the direction of human affairs by itself. (p. 225)

In addition to making the broad policy-level statements regarding the science curriculum, the Thirty-first Yearbook also provided an outline for the content of the curriculum at the elementary level.

The suggested elementary science curriculum was derived from the broad criteria described previously. The broad criteria were used to develop a series of content knowledge issues. The majority of these issues were developed so that the concepts could be learned through "activities, actual experience, simple discussions, and excursions." (NSSE, 1932, p. 180) In what would by the 1990s be described as a "habit of mind," the Thirty-first Yearbook (1932) authors also advocated that the "child may gain a simple appreciation of the scientific attitudes by realizing the relation between cause and effect." (p. 180)

2.1.3 Secondary Science Curriculum

The then-contemporary curriculum for secondary students did not engender quite the same degree of criticism as did its elementary equivalent, the Nature Study approach. The secondary curriculum was called to task more due to its exclusive focus on content knowledge than as a result of any particular philosophical orientation.

Many of the suggestions for the secondary science curriculum were derived from the report Cardinal Principles of Secondary Education (1918), a report by the Commission on the Reorganization of Secondary Education. The commission regarded seven objectives as the main goals of education:

> 1. Health 2. Command of fundamental processes 3. Worthy home-membership 4. Vocation 5. Citizenship 6. Worthy Use of Leisure [and] 7. Ethical character. (pp. 10-11)

The authors of the Thirty-first Yearbook adopted these goals. They were to provide the foundational principles upon which secondary science education would be organized. To take these broad instructional goals and develop them for the needs of the science curriculum, the science curriculum was examined in terms of biology and physical science. As might be expected, the focus was on the content required to master the discipline (NSSE, 1932).

> The course of study in biology in the schools...will consist of (1) such an understanding of...the principles listed earlier in this chapter...(2) an appreciation of some of the scientific attitudes exemplified in the works of such great biologists as Vesalius, Malpighi, Pasteur, and others, and a sense of the lawfulness of nature and of every man's obligation to obey such laws and other emotionalized standards; and (3) a reasonable degree of skill in the use of the scientific method of thinking on matters biological, so that the pupil will not go astray in his attempt to think through to a successful issue the biological problems with which he will certainly be faced. (p. 229)

The use of the scientific method was treated here as a piece of content to be understood as an end in itself. The view developed was typical of that of content area specialists; the body of knowledge must be mastered first. And, as one can infer from most classroom practice, the scientific method would be used to verify existing dogma rather than as a tool for exploration.

The physical science standards were similar in structure to those laid out for the biological sciences. A comprehensive body of knowledge was identified for students to be made aware of during their course of study. It is interesting to note, however, that some thought was given to reducing the amount of content and focusing more detail on fewer topics. This idea was revisited during the 1990s with the publication of the National Science Education Standards.

The differences between what was suggested for instruction--and the means of instruction--at the primary and secondary level was likely a matter of the author's background. At the secondary level, the focus was drawn from subject area specialists; the elementary level concerns reflected more of the influence of experts in curriculum and instruction.

These issues were reflected in an examination of textbooks on the topic of science teaching methods at the secondary level. The focus was typically on the content, more so than methods of conveying the science content. Howe's Systematic Science Teaching (1894) provided insights into the primacy of the content:

> An exactness of freedom in expression has been attained, and this the truest index of a mind full of observed facts, and trained to the thoughtful consideration of matters presented. (p. ix)

In more contemporary language, this reflected both an interest in the science content knowledge and the science process skills developed. While he reflected his desire for this duality of purpose in the preface to his book, Howe failed in the development of thinking skills during its following chapters simply by their omission.

Published later in this era, Brownell and Wade (1925) were able to blend the positions developed in the report Cardinal Principles of Secondary Education and the Thirty-first Yearbook. Reflecting the strong influence of the Cardinal Principles, these authors offered content on broader goals related to science education--character building, the role of the community, and moral education. Stated by the committee, there were several specific values of science education (The Commission on the Reorganization of Secondary Education, 1920):

1. The development of interests, habits, and abilities...
2. Teaching useful methods of solving problems...
3. Stimulation...[such that] science instruction should stimulate the pupil to more direct and purposeful activities...
4. Information values..[to] give the student control of a large body of facts and principles of significance in the home, school, and community. (pp. 14-15)

Hunter (1934) also reflected the role of the Cardinal Principles in his work Science Teaching at Junior and Senior High Levels, quoting them verbatim in a reflection on the purposes of science education. He recognized many of the difficulties content area-trained teacher have in achieving some of the more society-driven goals of education.

The study contained in the Thirty-first Yearbook was published when progressive education experts were at the peak of their influence. Despite this, there were few signs of progressive influence. The influence and

preeminence of the progressive educators, however, came into place by the publication of the Forty-sixth Yearbook in 1947.

2.1.4 Scientific Literacy

The objective of science teaching, by contemporary standards, is to produce scientifically literate students. This goal has been present throughout the history of science education. The Thirty-first Yearbook's (NSSE, 1932) statement on the objective of science teaching may be taken as their statement on what now would be considered scientific literacy.

> This Committee, then, recognizes the aim of science teaching to be contributory to the aim of education; viz., life enrichment. It recognizes the objectives of science teaching to be the functional understanding of the major generalizations of science and the development of associated scientific attitudes. (p. 57)

The stated view for what constituted scientific literacy, then, was to assist the student with the acquisition of scientific content knowledge and scientific attitudes toward the goal of life enrichment. With the passage of fifteen years and the publication of another Yearbook--the Forty-sixth Yearbook-- this definition was revisited and refined.

2.2 Forty-sixth Yearbook

Reflecting on the changes that had taken place in American society during the previous fifteen years, the Forty-sixth Yearbook (1947) concerned itself with the state of science education in American Schools. In particular, the rapid expansion of scientific and technological knowledge during the World War II years provoked a concern regarding the ability of traditional science education programs to keep pace with the explosion of information. Whereas the Thirty-first Yearbook concerned itself primarily with developing an overall program for science education in American schools, the Forty-sixth Yearbook moved beyond identifying the content needed for a comprehensive science program. The yearbook had three principles informing its content (NSSE, 1947):

1. To make the report as practical as possible...and to show how the daily activities of classroom and laboratory can be made to contribute to the ultimate goals of education in a democracy.
2. To review and appraise available research in science teaching and to suggest desirable types of problems for further study...

3. To select and describe the best practices in science teaching that could be found and to show how they can be adapted to daily use by any qualified science teacher. (p.2)

Thus, much of the Forty-sixth Yearbook was devoted to issues related to the teaching of science in the schools, rather than exclusively to the content. The role of progressive educators was more evident in the Forty-sixth Yearbook. In contrast with previous reform documents such as the Thirty-first Yearbook, a greater appreciation for the role of educators was evident. The purpose of science education had expanded beyond an expression of basic content knowledge to the more global goal of producing students who "develop an appreciation of ethical values which should undergird all life in a democratic society." (NSSE, 1947, p. 20) After 30 years, it seemed that the message of Democracy and Education had been more widely accepted.

With the above principles in mind, the committee developed these overall objectives (NSSE, 1947) for the teaching of science K - 12:

A. Functional information...
B. Functional concepts...
C. Functional understandings of principles...
D. Instrumental skills...
E. Problem solving skills...
F. Attitudes...
G. Appreciations...
H. Interests...(p. 29)

The ideal of scientific literacy held commonly by the 1990s was also evident in the documentation. The objective of producing a scientifically educated layman had moved beyond the attainment of a body of content knowledge and into the ability to solve problems.

> The development of competence in use of the scientific method of problem solving and the inculcation of scientific attitudes transcend other objectives in science instruction. (NSSE, 1947, p. 20)

And most importantly, in terms of the 1990s perspective on scientific literacy, this knowledge was desired for all students.

2.2.1 Progressive Influences

Nature Study, once it became the standard operating procedure in the elementary classroom, became subject to reconsideration of its value by a

new generation of progressive educators. Inside the front cover of the inaugural issue of Progressive Education, seven principles of progressive education were laid out. The first three points described the environment and circumstances in which student learning should take place. To the science educator, point 3 was of particular interest:

> The Teacher a Guide, Not a Task-Master...teachers will encourage the use of all the senses, training the pupils in both observation and judgment; and instead of hearing recitations only, will spend most of the time teaching how to use various sources of life activities as well as books; how to reason about the information thus acquired; and how to expand forcefully and logically the conclusions reached. (Progressive Education Association, 1924, p. i)

These issues of independent thinking, learning, and the consideration of science as an act of argument and judgment were fundamental principles upon which science education of the 1960s was based. They were also the principles under which the progressive educators attempted to organize their science instruction.

Moving beyond the broad principles of progressive education, more systematic efforts to identify what constituted the science curriculum were made. Dewey, in 1916, made these observations regarding the ideal classroom practice of science:

> By science is meant, as already stated, that knowledge which is the outcome of methods of observation, reflection, and testing which are deliberately adopted to secure a settled, assured subject matter. It involves an intelligent and persistent endeavor to revise current beliefs so as to weed out what is erroneous, to add to their accuracy, and, above all, to give them such shape that the dependencies of the various facts upon one another be as obvious as possible. (p. 219)

His vision clearly was moving science education beyond simply observing nature and developing empathy for the agricultural life. Dewey saw more than the "blank slate" some of the philosophers associated with the Nature Study movement might have postulated; he saw science--and most importantly, a scientific way of thinking--as a means to an end. The end, in his view, was a democratically engaged and productive citizen. Science gave the student tools of analysis and inference, and the ability to test information for its accuracy (Dewey, 1916).

> To sum up: science represents the office of intelligence, in projection and control of new experiences, pursued systematically, and on a scale due to

> freedom from limitations of habit. It is the sole instrumentality of conscious, as distinct from accidental, progress. (p. 228)

This "scientific" point of view infused much thinking during the progressive era: that education should be influenced by it as well was a given.

An article by Smith (1929) titled "Science as Play" demonstrated both the strengths and the perceived weaknesses of the progressive education model.

> The total amount of scientific information grasped may be trifling...In their play, then, the children identify themselves with the world of human endeavor, with its arts and sciences, its industries, and its social institutions. In the process they are learning to cooperate with others in common undertakings. They are learning that the greatest of all is the servant of all, for prestige in this small community, as in the greater one, comes to him who is of the greatest service to the community. (p. 190)

While heeding the principle of progressive education that the ultimate goal of education was to produce democratic, participating citizens, the ammunition for many future critics was offered in statements such as "the total amount of scientific information grasped may be trifling." (Smith, 1929, p. 187) In subsequent back-to-basics movements, a "trifling" of information would not be sufficient.

2.2.2 Elementary Science Curriculum

The elementary science curriculum, as conceived by the authors of the <u>Forty-sixth Yearbook,</u> reflected the focus on the use of the scientific method as a teaching and learning tool. Again, in contrast with the <u>Thirty-first Yearbook,</u> the development of student thinking and problem solving skills provided the core of the science experience, rather than the content knowledge. The thinking and learning skills represented habits of mind in the sense of Hurd's essay on the need for scientific literacy.

The Yearbook also provided a number of pieces on developing the curriculum to make the best use of community and school district resources. Technology, in particular, was identified as a key tool for the teaching and learning of science. Materials and methods for teaching in rural and urban settings were identified, with the suggestions that local community resources be adapted for instructional use. Clearly, the authors took their charge seriously to "make the report as practical as possible." (NSSE, 1947, p. 2)

The need for improved instruction was identified as well. Suggestions were made for teacher education competencies--improved content as well as instruction in pedagogy-- as well as the need for extensive and on-going staff development opportunities for practicing teachers.

All of the points covered in the Forty-sixth Yearbook's chapters on elementary science education suggested the need for long term, systemic improvement. Taken as a companion piece with the content orientation of the previous yearbook, the two documents together provided a comprehensive agenda for science education reform.

An examination of science methods textbooks published in the decade following the Forty-sixth Yearbook's release demonstrated some of the positions common to progressive educators. In Teaching Science to Children (Greenlee, 1951), specific suggestions were made for developing the appropriate classroom climate for science education: "let's study them as they play," "let's study them as they explore," "let's provide a permissive classroom atmosphere," and "let's provide activities for individual activities." These are concepts that would have found a comfortable home in any issue of Progressive Education. Similar views were expressed in Elementary Science Education (Wells, 1951) as part of a discussion of creating a more child-centered classroom.

> Formerly a dictator in a realm of cringing or sullen docility, the teacher suddenly finds herself considered as a helpful friend, a "wise owl" whose privilege it is to suggest a laboratory procedure and possible sources of information...(p. 17)

The secondary curriculum was not so quick to adopt the changes advocated by the progressive educators.

2.2.3 Secondary Science Curriculum

With the objectives of K-12 science education laid out early in the document, the focus of discussion on the specific topic of secondary science education recognized two trends. One trend represented the creation of more general interest and survey courses in science. The second trend was the increase in the absolute number of students taking science courses. Recognizing a change in the nature of courses offered and the ability to impact a greater number of students, the need for effectively addressing the needs of the students and the courses was clear.

Recognizing that many of the courses developed during the previous fifteen years were "survey" courses, the need to reexamine the purpose of the courses was critical. Due to the changing nature of the courses, the need to focus on the scientific method provided secondary teachers with a clear means of developing the courses. Moving to include the scientific method and problem solving skills as part of the secondary science curriculum brought out these comments:

> The elements of problem solving behavior will be obtained as objectives only to the degree that they are definitely sought and taught through appropriate learning experiences. (NSSE, 1947, p. 145)

Clearly the increased importance of the scientific method was evident.

As with the elementary level curriculum, the Thirty-first Yearbook advocated an extensive and comprehensive commitment to staff development for teachers. Suggestions for preservice teacher education were also made--no sharp distinction was made between the two. A number of specific suggestions were made as to teacher preparation. Consistent with the Thirty-first Yearbook, the majority of the coursework was devoted to content knowledge preparation. The study, however, went so far as to suggest that "the preparation of science teachers for secondary schools has been too narrow." (NSSE, 1947, p. 280) This represented a strong recommendation that teacher preparation programs offer coursework so that science could be understood as a member of the family of the humanities. In this way, instruction in the sciences was better connected to its purpose as a means of preparing students for participating in a democratic society. In essence, the movement was to

> Strike...out in the direction of liberal education in the social sciences, particularly as these can be related to scientific progress and developments. (NSSE, 1947, p. 280)

An examination of textbooks designed to prepare teachers for science instruction echoed this point. In an opening discussion of the purpose of science teaching in the secondary schools, Burnett (1957) stated that "a primary job of the science teacher consists of relating science to the progressive refinement of the democratic way of life." (p. 20) Burnett also anticipated two trends of the 1960s in a photo spread in his text. One was a need to produce more scientists "because of a national shortage of trained scientific talent;" (p. 22) the second featured a photograph of a young women, with the caption reflecting on the challenge of relating scientific knowledge to life experience. This second one clearly anticipated the objective of "science for all Americans."

Other texts of this era were scarcely affected by the more progressive trends of the time. In Richardson and Cahoon (1951), four paragraphs in the text were related to the purposes of science teaching, drawing upon three brief quotations from the National Education Association, the Progressive Education Association, and a study group at Miami University of Ohio. The remainder of the text was devoted to a discussion of scientific phenomenon and the means by which to demonstrate this in the classroom. By the late 1950s, Richardson had authored another text on science teaching. The shift in his thinking toward a more student-centered approach to learning was more evident, as measured by the inclusion of an entire chapter devoted to the topic of the significance of science in the curriculum. A term (Richardson, 1957) introduced to a larger public in his text was that of scientific literacy. He identified three reasons for this as a primary goal of science teaching.

> To make more effective decisions in personal, civic and national affairs...[to develop] a broad base of trained personnel in laboratories and on assembly lines...[and] the need in our society for leadership inculcated with the habits of critical thinking. (p. 1)

Consistent with the position Hurd had developed concurrently, the need for scientific literacy extended to <u>all</u> students.

The teaching of science seemed to have caught up with positions advocated by progressive educators thirty years previously. With changing circumstances came changing needs. By 1960, the political climate dictated that a number of revisions were needed in the nation's approach to science education. The launch of Sputnik, well ahead of U.S. capabilities, suggested that however well-intentioned were the science teaching and learning practices advocated by the <u>Forty-sixth Yearbook,</u> adjustments in the approaches advocated were clearly needed.

2.2.4 Scientific Literacy

"Education for all pupils for their own and for society's benefits" (Richardson, 1957, p. 61) included science education. The positivist position was that

> Through intelligent action, [humanity] may establish a higher standard of living on a worldwide basis. The solution of social problems in which science is involved cannot be accomplished through the work of experts alone...citizens can either assist or retard the work of the experts through

their votes and their conduct. In a democracy, all citizens have a responsibility in determining how science shall be utilized in a society. (Richardson, 1957, p. 61)

The ultimate goal of science education was still defined in two terms: the overall goals of a democratic society and the means by which instruction in science can help to achieve this end. The Committee (NSSE, 1947) identified four concepts by which an understanding of science could be achieved:

1. Functional understanding of information, concepts, and principles....
2. Instrumental skills....
3. Elements of the scientific method.... [and]
4. Scientific attitudes....(pp. 61-62)

The skills and knowledge base defined for scientific literacy in the Forty-sixth Yearbook provided the foundation for their later view of the purposes of science education. Thirteen years later, with the publication of the Fifty-ninth Yearbook and based on the groundwork laid out in two previous yearbooks, scientific literacy became the goal of science education in the United States.

2.3 Fifty-ninth Yearbook

The Fifty-ninth Yearbook was composed at the beginning of the educational era defined by the launch of Sputnik. Its subtitle, "Rethinking Science Education" underscored the purpose behind its publication.

One characteristic shared by the two previous Yearbooks was the specificity of their content. Specific suggestions on grade level content knowledge and suggested instructional methods were common. Specific suggestions were made in terms of content, delivery, materials, and even the organization of the classroom. The Fifty-ninth Yearbook, while making specific suggestions in the many of the same areas (materials, organization and delivery of instruction), took an even broader perspective.

The broad policy-level suggestions of the Fifty-ninth Yearbook (NSSE, 1960) were delineated thusly:

The objectives of science teaching as they appear have changed little in the past twenty-five years. On the other hand, there have been changes in the nature of the science taught; for example, the sciences have become more unified and have gained an important position in world affairs.

> These factors suggest the need to re-think the purposes of science teaching in the schools. (pp. 33-34)

The position of the Fifty-ninth Yearbook authors was that the objectives of science teaching were the same from K - 12. They saw that many of the problems associated with the teaching of science were related to classroom practice; other problems were systemic. To address these shortcomings as well as others perceived in the state of the practice, a number of broad issues were addressed to improve science education.

2.3.1 Rethinking Science Education

The "rethink" of science education covered an extensive set of issues. Issues in curriculum (developing elementary science programs, improvement of secondary science, organization of the curriculum), teacher preparation (education and professional growth of the science teacher), facilities (facilities and equipment), learning theory (needed research in science education, how individuals learn science) and accountability (supervision of the science program) provided the broad areas for discussion. The areas of interest were much more broadly defined that in previous Yearbooks.

Perhaps the most striking area of departure was in the area of developing a commitment to research in improving the state of science education. There is, upon reflection, the implied message that "everything will be all right if you simply do as we suggest." The Fifty-ninth Yearbook devoted several chapters to research issues in science education. Both the then-current state of learning theory as well as proposed areas for investigation were offered for consideration and action.

Events outside of the education community had their impact multiplied within education.

2.3.2 The Sputnik Effect

The most significant political and technological event of 1957 was the successful launch by the Soviet Union of the first artificial satellite. The impact of Sputnik's launch was felt keenly throughout society. An editorial account in the The New York Times, reflecting on the Soviet's success, stated:

> It was Soviet scientists and technicians who built and launched this concrete symbol of man's coming liberation from the forces which have hitherto bound him to earth. To them must go the congratulations of all

> humanity. This is a feat of which all mankind can be proud. (The New York Times, 1957, October 6, p. E10).

Running parallel to this account in the same newspaper were more ominous reflections on other consequences of Soviet technological superiority:

> The other is the road of despair and disaster, the road which is followed if the great achievements of universal science are used for the purposes of aggression, death and destruction. (The New York Times, 1957, October 6, p. E10).

The ultimate American interpretation of these events focused more on the latter statement. In an article running in the same edition of The New York Times this question was posed (Schwartz, 1957, October 6):

> In the wake of the historic Soviet space satellite achievement, the question arises: How did they do it? And immediately after that, comes the corollary question: How was it possible for the Soviet Union to outstrip the United States by so wide a margin of time and quality of accomplishment? (p. E3)

The author (Schwartz, 1957, October 6): then offered these comforting thoughts:

> Certainly no American need feel ashamed of the state of science in this country or of the capabilities and contributions of our own physical scientists and mathematicians. (p. E3)

Outside of the conciliatory tones in the Times, the consequences were considered too grim for further Soviet successes. America's educational institutions were not producing enough engineers and scientists, and all efforts would be made to change the status quo.

The political reaction was swift. In 1958, Congress passed the National Defense Education Act. Its purpose was to support student grants and fellowships to study mathematics and science, as well as for the purchase of materials for schools. (Bybee, 1997, p. 9)

As another measure of the federal government's commitment to changing science teaching practices, funding for science education research provided by the National Science Foundation (NSF) jumped from $130,000 in 1955 to $40,000,000 in 1959. (Carin, 1997b) With the infusion of money came new programs and approaches toward the teaching of science. Many of these projects were characterized by the participation of scientists, educators, and

psychologists, who were all committed to providing a curriculum which would prepare students to function one day as scientists. High school science programs such as Physical Science Study Committee (PSSC) and Biological Sciences Curriculum Study (BSCS) moved the study of physics and biology far from the observations and anthropomorphisms of the Nature Study movement. Students were engaged in discovering physical principles and developing models of physical systems. At the elementary level, science curriculum projects such as Elementary School Science, and Science: A Process Approach (ESS and SAPA, respectively) were unveiled during the early 1960s.

These elementary programs were characterized by several qualities. First, they were committed at the outset to produce more scientists and engineers. To this end, the experiences of the students would reflect the practices of scientists: the programs were based on a process of scientific inquiry. Second, many of the programs were rooted in the theories of developmental psychologists such as Piaget. Finally, the idea of science process skills was enumerated and made a part of the curriculum along with the more traditional focus on science content knowledge.

While the programs derived from these efforts were more than satisfactory, the decrease in funding allotted to development and teacher training eventually took their toll on many of these science curricula. Noted Carin (1997a): "progress depends on funding from the National Science Foundation." (p. AP-4) With economic chaos creating havoc during the 1970s and early 1980s, the earlier recommendations were changed to the form of less expensive policy statements rather than significant teacher training and curriculum development.

2.3.3 Theory into Action

A virtual companion piece to the Fifty-ninth Yearbook was the National Association of Science Teacher's document Theory into Action. Theory into Action recognized the policy level implications of the Fifty-ninth Yearbook. It identified the need for the theoretical practices advocated in the yearbook to find practical expression in the act of teaching science.

Theory into Action (National Science Teachers Association Curriculum Committee, 1964) began with a statement of the purpose of science education:

> *Science teaching must result in scientifically literate citizens.* [italics in original] Goals of education tend to be an expression of American values. They describe what the ideal American citizen should be like. As such they remain stable over fairly long periods of time. Our conception of the ideal does not change very rapidly. What changes are our ideas of how to achieve the ideals expressed through the goals. (p. 8)

Coincidental with the publication of this document the powerful science curricula of the 1960s were developed. The curriculum goals of the Theory into Action document found expression in a number of different curriculum projects for elementary and secondary science education.

2.3.4 Elementary Science Curriculum

"A dynamic society must expect that its teachers will be able to perform the new tasks that fall to them." (NSSE, 1960, p. 281) This was the challenge offered to teachers in the light of the new geopolitical order. With Sputnik a sign of the need for change, and generous funding available for science education, an age of curriculum projects and staff development programs was inaugurated.

The elementary curriculum of this time, as mentioned previously, was characterized by a number of curriculum projects. Each of these projects typically was organized around a framework of one sort or another. The American Association for the Advancement of Sciences' Science--A Process Approach (SAPA) provided a well-documented example. In this program, two pedagogical assumptions were made: materials needed to be prepared with the child's intellectual growth as a concern and with a long-range view toward the acquisition of intellectual skills. Thus, the curriculum framework revolved around a set of process skills that allowed students to acquire and analyze information in a meaningful way (Hurd and Gallagher, 1968).

Other programs were developed in a similar fashion. The Elementary Science Study (ESS) program provided another example; its approach to science relied on the theories of psychologists such as Hunt, Berlyne, and Bruner. In the ESS program, ample time was allowed for students to engage in free exploration of areas of interest. The activities were designed so that children could examine relationships between humans and their physical world, and to allow for a difference in interests and abilities.

ESS, SAPA, and the other projects were designed as comprehensive programs. Hands on materials, teacher's guides, student worksheets, and

pamphlets were all made a part of these programs. Staff development programs were made available for teachers who wished to make use of the materials, and funding was made available for their continued development.

Twenty years after these programs were developed they were considered part of the established background from which teachers could draw. This perspective was shown clearly in the 1984 text Elementary Science Methods (Henson and Janke). That text offered background information on SAPA, ESS, and other elementary science curricula; it also reflected some of the realities of decreased funding and training opportunities by examining elementary science textbooks as a significant part of the curriculum.

2.3.5 Secondary Science Curriculum

The Fifty-ninth Yearbook authors described the science teacher at the secondary level as

> Emerging from a position of a purveyor of information to that of a social architect whose competence is in science. The needs of our society assign new functions to him; his professional growth must be governed by these changing functions. (NSSE, 1960, p. 281)

The changing functions, related to the increasing technological and scientific sophistication of the times, suggested that the role of the teacher needed to be more broadly defined. As with the elementary curricula, the role of the content needed to be considered in a different manner:

> Content must be regarded as both an important vehicle and a product of the experience in science. The science teacher must relate the science curriculum to the activities in science through which the students' special interests and abilities can find more adequate expression. (NSSE, 1960, p. 281)

Clearly, the needs of the students were considered a more important part of the science education experience. As part of these new ideas about the teaching and learning of science, a number of curricula were introduced at the secondary level. BSCS biology and PSSC physics were among the most notable of the post-Sputnik era of textbooks and curricula and are still in use in recognizable forms by the late 1990s. The activities, structure of the courses, and even the photographs in the texts are still present in (new and updated forms) in the texts of the late 1990s.

The trends described in the Yearbook had two issues in common. One was the identification and development of the ablest students--students who

were destined to become future scientists. The other trend was directed toward the "toughening" of the secondary curriculum. (NSSE, 1960) In general, making science available to all students as a means of achieving scientific literacy was not the prevailing concern.

Textbooks designed for the preparation of science teachers further emphasized these points. Here is one excellent example of how the process skills had further infused the teacher education curriculum: "Science is both a body of knowledge and a process" (p. 1) opened the second paragraph of Sund and Trowbridge's (1967) text Teaching Science by Inquiry in the Secondary School. This helped to establish that thinking and learning skills were a part of the learning equation along with the content knowledge. It was a departure from the extreme content-centric focus typical of most secondary science teachers.

2.3.6 Scientific Literacy

Hurd's definition of scientific literacy, despite his involvement in the creation of the Fifty-ninth Yearbook, was not completely evident. The glimmer of its essence--related to the "toughening" of science knowledge for all students--was the suggestion of the idea of science knowledge for all. The second strand common to the secondary science programs of the era--that of providing special experiences for the gifted students (and potential scientists)--showed that many of the contemporary efforts were directed toward a smaller group of students rather than the general population.

2.4 The Era of Reform: The 1980s-1990s

During the 1970s downturns in the American economy, falling standardized test scores, corruption in government, and the affects of America's involvement in the Vietnam conflict called into question the effectiveness of many of America's institutions. As during the Sputnik era of a previous generation, education increasingly was tagged the cause of many of the problems the country was facing--as well as the potential solution. A series of reform documents were initiated during this time. Each has contributed to the discussion of the proper purpose of education; each offered insights into what constituted the idea of scientific literacy.

2.4.1 A Nation at Risk

A quote from A Nation at Risk opened this chapter; in an increasingly conservative era, it provided ammunition for those who sought to criticize

education and restore it to its proper role in teaching the "basics." While A Nation at Risk was not solely concerned with science education, as had been the previous documents, it received wide publicity and stimulated much public debate over the state and fate of education.

The document identified a number of indicators of risk; several topics in science were among them:

> College Board achievement tests ... reveal consistent declines in subjects such as physics...
>
> There was a steady decline in science achievement scores of U.S. 17-year-olds as measured by national assessments of science in 1969, 1977, and 1979. (NCEE, 1983, pp. 8-9)

Adding to the concerns regarding the quality of science instruction were the findings that there was a shortage of science teachers in the majority of the states. In the case of physics, it was stated that only one-third of U.S. schools offered physics taught by a qualified teacher. (NCEE, 1983)

The solution to these and other identified shortcomings came in the form of higher standards for students and for teachers. The "new basics" identified for high school students a need for three years of science and one-half year of computer science. The recommendations for the curriculum included this description of a comprehensive science program (NCEE, 1983).

> The teaching of science [emphasis in original] in high school should provided graduates with instruction in: (a) the concepts, laws, and processes of the physical and biological sciences; (b) the methods of scientific inquiry and reasoning; (c) the application of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and technological development. Science courses must be revised and updated for the college-bound and those not intending to go to college. (p. 24)

To achieve these instructional goals, the need for more time and higher standards of performance were identified, along with the need for increased funding. Teachers were also identified as being in need of higher standards in their preparation. Interestingly, despite the call for greater proficiency among teachers, the recommendation was also made for the employment of individuals with appropriate content knowledge but with minimal pedagogical skills or experience.

A Nation at Risk raised the national awareness of problems in the American educational system. Responses to its recommendations were typically legislated in terms of "higher standards" for students, without providing the funding for accomplishing the more fundamental changes.

A Nation at Risk also provided the background and necessary starting point for a series of reform documents related to science teaching. Its broad issues were developed in greater clarity and detail with the development of Project 2061 and the National Science Education Standards.

2.4.2 Project 2061

Project 2061, by its very name, recognized the long term challenges associated with producing change in the curriculum. This initiative, sponsored by the American Association for the Advancement of Science (AAAS), selected the anticipated return date for Haley's comet to emphasize the long-term nature of this project. The program was highlighted by several publications: Science for all Americans, Benchmarks for Science Literacy, and Resources for Science Literacy. Each of these identified the direction of science education during the late 1980s and 1990s, in particular the promotion of the notions of scientific literacy.

Science for all Americans. This text provided the conceptual groundwork for the remainder of Project 2061. Much as with earlier documents such as the Thirty-first Yearbook, and Kurd's essay in Educational Leadership, the case was made for science as a member of the liberal arts. Instruction in the sciences, then, should reflect their role in society. The project was based on these principles (AAAS, 1989):

> World norms for what constitutes a basic education have changed radically in response to the rapid growth of scientific knowledge and technological power.
>
> U.S. schools have yet to act decisively enough in preparing young people--especially minority children, on whom the future of America is coming to depend--for a world shaped by science and technology
>
> Sweeping changes in the entire educational system from kindergarten through twelfth grade will have to be made if the United States is to become a nation of scientifically literate citizens.

> A necessary first step in achieving systematic reform in science, mathematics, and technology education is reaching a clear understanding of what constitutes scientific literacy. (p. 11)

Benchmarks for Science Literacy. The Benchmarks document provided a tool for curriculum planners. The "benchmarks are statements of what all students should know or be able to do in science, mathematics, and technology by the end of grades 2, 5, 8, and 12." (AAAS, 1993, p. ix) Though intended as a curriculum design tool, Benchmarks was designed to be flexible enough to allow for diversity in instructional methods. The content knowledge specified in the document represented thresholds of understanding, rather than average or advanced performances--it was designed, as implied by Benchmarks' companion volume, to provide science for all Americans.

The scope of knowledge thresholds contained in Benchmarks covered a common core of knowledge in science, math, and technology. As a departure from previous documents, the interaction with science, mathematics, and technology was considered with the customary view of producing a functioning citizen.

Documents such as the Forty-sixth Yearbook saw the goal of science education as one tool towards the development of a democratically participating citizen. While this broader goal was still implied within the Project 2061 documents, the need to integrate science instruction with mathematics and technology (in the sense of technology as a subject) was developed in detail. In the context of Project 2061, the Science-Technology-Society (STS) curriculum represented the optimum strategy for achieving the broad goals of education. Studies (Meyers, 1996) showed that "science taught with an STS focus is effective in stimulating student learning of science concepts," (p. 56) a goal of both science teachers and among members of the general public. Improved process skill acquisition also was shown to be associated with the STS curriculum (Wilson and Livingston, 1996). Documentation also showed that the quality of student interaction with the STS curriculum in terms of positive attitudes towards science (McComas, 1996)--and success for minority students (McShane, and Yager, 1996)--was also associated with this approach. Given that the inclusion of all students was a contemporary goal of scientific literacy, these benefits cannot be denied.

Resources for Science Literacy. The Resources for Science Literacy provided the most recently presented document in the series of AAAS tools to improve science education. Like the issues identified in the yearbooks on science education, the need for staff development and teacher resources was emphasized. Resources for Science Literacy made inroads into many of the needs identified for teachers in a single comprehensive document. In addition to the text material, the package included a CD-ROM with a number of useful resources identified was included. Six components were developed for the CD-ROM. The entire text of Science for all Americans was included to provide the context for the remainder of the disk. In an effort to promote more effective instruction a compendium of tradebooks was listed, as well as a comparison of Benchmarks for Science Literacy to three other sets of educational standards: the National Science Education Standards, the Curriculum and Evaluation Standards for School Mathematics, and the Curriculum Standards for Social Studies. (AAAS, 1997) Further issues in the instructional domain were attended to by an introduction to cognitive research and a description of college courses that prepared students with concepts derived from Science for all Americans.

As befits a program with a long term commitment to systemic change in science education, further documents were planned to assist in changing instruction in the sciences to better reflect the current conception of what constituted scientific literacy.

2.4.3 National Science Education Standards

The National Science Education Standards (NSSE), published in 1996, represented a systemic approach to change in the practice of science education. Concerned with more than the curricular changes needed to achieve scientific literacy, the NSSE identified broad areas within the entire system that needed to be addressed.

The organizational framework for NSSE attempted to present and identify the needs of science education in these areas (National Research Council, 1996):

Standards for science teaching
Standards for professional development
Standards for assessment in science education
Standards for science content
Standards for science education programs
Standards for science education systems (p. 3)

Much as did Project 2061, the National Research Council (NRC) produced a comprehensive view of the needs for science education systems. Recognizing that change cannot take place in isolation, the NSSE identified various systems that required change and development to achieve the goal of scientific literacy for all students.

2.4.4 Elementary Science Curriculum

The elementary curriculum by the 1980s reflected over twenty years of commitment to a hands-on approach to learning science. Authors of science methods textbooks published during the reform era advocated a number of issues in common with each other.

The hands-on/minds-on approach to science education was adopted uniformly across the field by the 1980s. Authors such as Carin (1997b), Howe and Jones, (1993), Zemelman, Daniels, and Hyde (1993), and Martin, Sexton, Wagner, and Gerlovich (1998) characterized this approach. Furthermore, the notion that all students should achieve a degree of scientific literacy was institutionalized. Texts such as Barba's (1997) Science in the Multicultural Classroom underscored this point. Citing the National Science Education Standards, Barba stated "that each child develops scientific literacy...is the primary goal for science teaching and learning." (p. 194)

2.4.5 Secondary Science Curriculum

The secondary science curriculum of the reform era was characterized by many of the same issues that informed the elementary curriculum. Curricula designed for secondary students was clearly informed by the desire to achieve scientific literacy.

Authors such as Victor and Kellough (1997) offered insights into the effect of the various science teaching and learning standards on the secondary methods books. The goal of instruction was to produce a scientifically literate person. A scientifically literate person (SLP)

> knows the social implications of science and recognize the role of rational thinking in arriving at value judgements and solving social problems. The SLP knows how to learn, to inquire, to gain knowledge, and to solve new problems. Throughout life the SLP continues to inquire, to increase his or her knowledge base, and uses that knowledge

> to self-reflect and to promote the development of people as rational human beings. (Victor and Kellough, 1997, p. 16)

This statement showed the evolution of the notion of scientific literacy as clearly different from the traditional, content-only approach more typical of secondary school practices.

2.4.6 Scientific Literacy

By the 1990s, the concept of scientific literacy had developed into the focus for the purpose of science education.

The AAAS and the NSSE provided two compatible views of what constituted scientific literacy. Indeed, the documents were more notable for their similarities than for their differences. The critical point common to each was the need for students to be prepared in such a way as to develop their literacy in science. According to the National Research Council (1996):

> Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity. (p. 22)

The American Association for the Advancement of Science (1993) suggested that those who are scientifically literate:

> Use the habits of mind and knowledge of science, mathematics, and technology they have acquired to think about and makes sense of many of the ideas, claims, and events that they encounter in everyday life. (p. 322)

The two key elements shared by these definitions of scientific literacy related to

1. Attaining a knowledge of science, and
2. Using this knowledge to one's advantage in everyday life.

This theme has been present throughout this century. The relative emphasis on attaining knowledge versus the use of knowledge was a reflection of the time. The current view has held sway since Hurd's 1958 essay, showing its roots in progressive education and in the post-Sputnik need for trained scientific thinkers.

3. SUMMARY

The evolving definition of scientific literacy has been evident through the practice of science education throughout the twentieth century. The notion that students should have a command of the content and processes of science has been in place for most of this century. What occurred as the century progressed was an expansion of the goal to include all students. In the 1950s, Hurd's essay captured the essence of the need for a scientifically educated populace; by the 1990s, the idea of scientific literacy had formed the core of what science education should comprise.

Related to the evolution of the concept of scientific literacy was an observation by Bybee (1997) that one of the critical differences between the science education movements of the Sputnik era compared to those conceived during other times was that Sputnik era reforms were not organized through the development of policy statements. Most of the reforms of the 1960s tended to be curriculum packages and curriculum reforms, without the overarching structures of being part of a reform movement.

The reform movements of the 1980s and 1990s provided several competing, yet compatible views of the scientifically literate student. Reformers recognized the need for a scientifically educated student body, wise in the ways of science, technology, and society. A precise means of implementing the goals and policy remained a critical need through the end of the 1990s.

With the context of one hundred years of science education providing the background, we may now turn to an examination of technology and its applications in science education during this century. A “how to” statement regarding the use of technology in the classroom was needed 100 years ago; it would still be of use today. How technology has been a means of enhancing scientific literacy provides the organizing principle for the remainder of this study. The assorted successes and failures using technology to achieve this end provide the narrative. The next chapter will begin that process by examining the role of the motion picture in science education.

Chapter 3

The Motion Picture

One Hundred Percent Efficiency

In 1922 Thomas Edison made the following statement regarding the use of the motion picture in instruction:

> I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks.
>
> I should say that on the average, we get about two percent efficiency out of schoolbooks as they are written today. The education of the future, as I see it, will be conducted through the medium of the motion picture...where it should be possible to achieve one hundred percent efficiency. (Cuban, 1986, p. 9)*

The wizard of Menlo Park played a significant role in America's infatuation with technology, receiving several hundred patents over the course of his life. Many of his inventions and their direct technological descendants are still in use today. Also present is the attitude that technology can help us to achieve closer to "one hundred percent efficiency" in our daily tasks--including education. Looking back from the future Edison envisioned, the goal of "one hundred percent efficiency" has not been achieved, yet technology has impacted science education in ways that scarcely could have been conceived. The film was one of the first electrical-mechanical technologies to enter the domain of education. To begin this investigation, an overview of the technology itself is helpful.

* It is also worth considering that Edison's enthusiasm for the motion picture is likely related to his having invented this particular technology.

1. BACKGROUND: DEVELOPMENT AND ADOPTION OF THE TECHNOLOGY

The motion picture is an excellent example of a technology that was heavily reliant on previous inventions, rather than an innovation that sprang forth, fully developed. It assumed a secure place among the American public as motion picture entertainment rapidly captured peoples' imagination.

1.1 The Development of the Technology

The motion picture can identify its most significant technological ancestors as the camera and the projector. Applications of these simpler technologies were seen in the work of Eadweard Muybridge (Mast, 1981).

> In 1872 [Muybridge] was hired by the governor of California, Leland Stanford, to help win a $25,000 bet. Stanford, an avid horse breeder and racer, bet a friend that at some point in the racehorse's stride, all four hooves left the ground. In 1877, after five years of unsuccessful research, Muybridge set up twelve cameras in a row along the racing track. He attached a string to each camera shutter and stretched the string across the track. He chalked numerals and lines on a board behind the track to measure the horse's progress. Stanford's horse then galloped down the track, tripping the wires, and Mr. Stanford won $25,000 that had cost him only $100,000 to win. (p. 11)

This first step--of capturing a series of a horse's footfalls in sequence--was in essence the reverse of the process by which the motion picture worked. Any child familiar with making a series of small drawings on the corner of a tablet, each slightly different from the previous one, and then flipping rapidly through each page, has duplicated the fundamental concept underlying the motion picture. Muybridge's sequential photographs, were they projected rapidly to the human eye, would produce the impression of a horse in motion.

The master inventor-businessman, Thomas Edison, took on the challenge of developing the motion picture in its recognizable form. Edison originally was more interested in documenting his previous inventions with his newest creation; the possibilities that film offered did not immediately capture his attention (Mast, 1981). As such, his interests in the media were split between a single person viewing apparatus--a "peep show" device called a Kinetoscope, and a more public display forum. Edison focused primarily on the Kinetoscope. Edison's laboratories produced the earliest complete film

on record in 1890. Thousands eventually were entertained by the short film Fred Ott's Sneeze.

Edison neglected to extend his patent on the new technology to Europe; as a result, subsequent developments were not produced in Edison's laboratories. The primary technical challenge remaining was to develop a means of projecting the images with sufficient brilliance and clarity that a group of individuals would be able to view the motion picture.

The French brothers, August Marie Louis Lumnière and Luis Jean Lumnière moved the film ahead technologically. Several improvements developed by the Lumnières helped advance the motion picture: portability, creating one machine that both printed and projected the pictures. Then, by projecting a light was through the lens when showing the motion picture, the images were presented in a large group setting rather than to an individual viewer (Mast, 1981). Compared with Edison's one viewer Kinetoscopes, the Lumnières' public demonstrations of the technology were startling. Their motion picture of a train rushing into a station had people shrieking and ducking as the train came hurtling in the audience's direction (Mast, 1981).

1.2 Public Use of Technology

The motion picture rapidly assumed a status as a popular form of entertainment. Movie houses opened rapidly during the first decades of the twentieth century; by the mid 1920s, teachers were reflecting on the competition offered by motion pictures for their students' attention. By the end of the 1930s, over eighty-five million Americans attended a motion picture each week. (Thorp, 1939) So pervasive a presence was the motion picture that its movement into the classroom was inevitable.

Thorp (1939) commented on the informal nature of films as instructional devices in the early years of the century:

> The enormous amount of general information absorbed by the movie going child and the painless ease by which it is retained have long been a cause of heart searching to educators. The small-town boy in Vermont or Arkansas who has never in his life been fifty miles from the farm is now quite at home on the *Place de la Concorde*, Broadway at midnight, the Himalayas, or any one of a dozen South Sea islands. He knows something about coal mining, about radio broadcasting, deep sea fishing, and bridge building....(pp. 19-20)

The challenge faced by science educators, then, was to make the "general information" described by Thorpe more specific, and apply it to the goals of science teaching.

1.3 Educational Advocates

As early as 1902, non-theatrical uses of film were in evidence. Early examples of educational film were "the newsreel, the travelogue, and the scientific motion picture." (Saettler, 1990, p. 96) Setting the stage for eventual developments in America, Saettler (1990) recounted several early examples of educational film:

> ...by 1902 Charles Urban of London had exhibited some of the first educational films, and films with slow-motion, microscopic, and undersea views were beginning to be produced. These films included such subjects as the growth of plants and the emergence of a butterfly from the chrysalis. In... 1904, at the Marey Institute in Paris, Marey and his associates filmed the flight of insects, the locomotion of animals in water, the digestive process of small animals, and the heart in action. (p. 96)

Training individuals in the use of the technology provided an area of exposition for numerous individuals. The information presented in <u>Optic Projection</u> (Gage and Gage, 1914) resonates with contemporary readers who have are frustrated with instruction in RAM, ROM and hard drive space when their real concern is how to compose an essay with a word processing program. The Gages detailed the physics of image formation as it applied to motion picture and magic lantern presentations, in the hope that

> [with] such simple and explicit instructions ...any intelligent person can succeed in all the fields of projection; and our hope is the book will serve to make more general this graphic art by which the means of many persons can be appealed to at the same time and in the most striking manner. Furthermore we believe this art has great, undeveloped possibilities for giving pleasure, arousing interest, and kindling enthusiasm, in that it provides for the ... demonstration of maps, diagrams and pictures of all kinds, the structure and development of animals and plants, many of the actual phenomena of physics and chemistry, and finally scenes from nature and from life, even with their natural motions and colors. (p. iii)

To achieve their enthusiastic aims, the text provided a highly technical overview of the physics of image formation and the advantages of the various technologies then available. Sadly, many of the issues that would

bring an instructor to use this technology in the classroom were addressed only in the preface; yet these motivational and instructional did contributed significantly to the body of the text. Care and maintenance of these expensive tools were also included, in the hopes that the technology would achieve a long and successful classroom life.

A 1920s era study (Wood and Freeman, 1931) examined the issue of using motion picture technology as a means of improving science instruction. The study compared coverage of similar science topics, with the single difference in instruction being that the experimental group had access to motion pictures to assist in the learning process. Findings indicated that only 38 percent of the control group showed the same gains as the students who were exposed to motion pictures as part of the learning process. Teachers, when surveyed as part of the study, responded that the films were

> highly effective (1) in arousing and maintaining interest; (2) in increasing the quantity and quality of the reading, project work, classroom discussion and writing; (3) in promoting a more thorough correlation of the materials on the part of the pupils; (4) in increasing the richness, accuracy, and meaningfulness of their experience; (5) in facilitating the work of the teachers in organizing the lesson materials and in making teaching more pleasant and the self-activity of the teachers greater. (Wood and Freeman, 1931, pp. 118-119)

Findings such as these were not lost on the National Society for the Study of Education. In the <u>Thirty-first Yearbook: A Program for Teaching Science</u> (1932), the need for using technology as a teaching tool was addressed. As part of the proposed program for teaching science, needs associated with the effective instruction of science--curricular, pedagogical, philosophical, and material--were examined. In an extensive chapter devoted to the requirements for science rooms and equipment, a strong case was made by the National Society for the Study of Education (NSSE, 1932) for infusing technology into the science experience.

> Science rooms should provide certain facilities for objectification by means other than the use of concrete materials. This guiding principle calls attention to such items of equipment as the blackboard, bulletin board, display fixtures, charts, and most especially the materials included in the term *visual instruction.* Glass slides, home made slides, film slides, micro-slides, opaque projectors, the motion picture and the "talkies," all have a valuable place in science teaching. They can provide experiences as real to the pupil as many of the demonstrations and laboratory exercises. Often they surpass the latter in variety, clarity, and

> pertinence. When properly used, they supplement other experiences, fill in gaps, and tie together ideas that belong together. (p. 294)

These issues connected strongly with the 1930s view of the purposes of science education. Acquiring "functional understanding of the major generalizations of science and the development of associated scientific attitudes" (NSSE, 1932, p. 57) can most successfully attain the purpose of science education, life enrichment. The motion picture, its advantages enumerated above, clearly helped to achieve the desired grasp of science.

Not all the data gathered with respect to its use in instruction. Freeman (1924) reported on the findings of studies conducted by Hollis and Rolfe. In these studies, it was demonstrated that when comparing instruction by motion picture to that of a teacher performing a demonstration, students seeing demonstrations displayed greater proficiency in duplicating the activity. Rolfe (1924) examined learning in terms of the students' ability to engage in a task when presented comparable information in a motion picture and in a teacher-led demonstration. As summarized previously by Freeman, the findings supported the position that actual involvement in the activity was superior to a virtual experience provided by the motion picture. Thus, evidence was present from the earliest days of the motion picture in education that technology does not represent a panacea for all of education's ills.

Recognizing the engaging nature of the motion picture as an instructional tool, Hunter (1934) offered these comments:

> Most science teachers discovered the value of visual aids long before the movies and talkies began to find a place in the classroom. Free use of charts, models, and lantern slides has for years been considered indicators of good teaching. But today the movie house has developed so great a following that, if we are to compete with the outside attractions, we would seem bound to include the movie and the talkie as definite motivating devices to be regularly used in the science laboratory. (p. 294)

If the words "television" and "computer games" were substituted for "movie" and "talkie," his statement would sound strikingly contemporary.

Beyond the engaging quality of the technology, the utility provided by the motion picture was what led teachers to adopt it as one of their classroom tools. Motion pictures, reported Fern and Robbins (1946), provided aids to understanding "scientific theories, rules, formulae, and their applications," (p. 79) consistent with the goals of scientific literacy.

The Second World War provided a significant boost for those who were the pioneers in using the motion picture in education. Significant resources were committed to produce quality training films for the troops and education films supporting the war effort for those who remained at home. The successes enjoyed from the use of these films provided further encouragement for those whose interest fell in the domain of science education.

Shortly after the end of the war, with the publication of the Forty-sixth Yearbook, the motion picture had become, along with chalkboard and textbooks, institutionalized as part of the teachers' repertoire of classroom tools.

The Forty-sixth Yearbook, in 1946, was able to absorb and further transmit much of the enthusiasm for the use of motion picture technology in science education.

> Motion pictures and slidefilms may be used to achieve many of the objectives of science education. Motion pictures and slidefilms are in most cases the next best thing to direct experience when such experience is impossible. In addition, they have two special values. They may depict excellent instruction, thus serving as a model for the effective use of equipment and materials in teaching science, as well as illustrating good method and content. Also, they may, by virtue of their unique characteristics, illustrate scientific phenomena that cannot be seen by the naked eye, such as the solar system, bacteria, and the structure of the atom. The inherent characteristics of the motion picture, including animation, microphotography, time-lapse photography, and slow motion, make possible a realistic understanding of abstract subjects and events of scientific interest. (p. 101)

This constituted strong praise for and confidence in the use of the motion picture in science education. Educators can at times be skeptical consumers of the newest technology or technique. That film so rapidly entered the instructional pantheon spoke well of its perceived virtues.

2. THE MOTION PICTURE IN THE CLASSROOM

Motion picture technology has been present since the early part of the century. Its use continues, albeit in altered form, to the present. How its

presence influenced the science classroom provides the next area of investigation.

2.1 The Motion Picture

During the motion picture's formative years in the science classroom, several factors characterized its use. An examination of the science education literature of this era revealed three types of discussions related to the use of the motion picture in the science classroom. Descriptive articles regarding schools that had acquired the technology characterized the early years. This introductory phase led next to articles that examined the successes that characterized instruction using the motion picture. These articles tended to be related to experimental studies involving the use of the technology. Suggestions for informed teaching practice emerged from these articles.

The final cluster of articles represented the institutionalized phase of the technology. At this juncture, preferred practice with the use of the motion picture had been established; journal articles now sought to inform the science educator as to the best choices in terms of software to achieve their educational goals. A review of available films is an excellent example of this phase of the literature's evolution.

The first article on the use of motion pictures in science education in the journal School Science and Mathematics was published in 1913. It consisted entirely of a listing of schools that had acquired motion picture equipment for use in science and mathematics education (Levier, 1913). Sadly, no commentary was offered in terms of how the technology was used--simply a listing of schools and the courses which the technology supported. This also underscored one of the initial phases in the infusion of technology into teaching--the acquisition of the hardware itself. The second article on the topic of motion pictures in School Science and Mathematics was published later in the same year. Reporting from Germany, motion pictures were said to have "had a real impetus in German official circles." The motion picture was applied to instruction in the "anatomical, biological, and bacteriological courses." (School Science and Mathematics, 1913, p. 797) As with the previous article, the text offered little for those who wished to investigate the use of the motion picture as a tool in teaching, and provoked more questions than answers.

Among the scholars of this early period, the movement towards embracing technology was limited. In a profile of the contents, methods,

and resources for an exemplary general science course (Roecker, 1914), no mention was made of the motion picture, let alone lantern slides or other forms of instructional technology.

As was often the case, technology found war to be a catalyst for action. By the end of the First World War, many of the training films were repurposed for the needs of the public at large. Science and mathematics teachers were alerted through the journal School Science and Mathematics (1919) as to the availability of numerous films created in support of the conflict which were now available to the public.

The need for appropriate software provided one of the key educational issues in the area of motion picture technology in the science classroom. Finegan (1928) outlined some large-scale commercial efforts to develop and test appropriate software for the science classroom. Researchers at the Eastman Kodak Company produced a series of classroom films with the cooperation of leading educators.

The company's interest in the medium, doubtless influenced by their commercial interest in cameras and film, led to surveys of educators to determine why motion picture technology was so seldom infused into the science curriculum. The findings of the survey (Finegan, 1928) suggested that

> In substance...little had been accomplished in the production of suitable films for classroom service...[and] there appeared to be little prospect that an organization with sufficient resources would enter upon a program to produce films of this type on an adequate scale. (p. 392)

With the need for this sort of software established, Kodak set out to develop a series of films appropriate for science instruction and test the efficacy of instruction with film and without. At this time, much of the research was exploratory in nature:

> A few experiments in this field have been conducted in this country and in Europe, but the extent and the general scope of such experiments has been wholly inadequate in the results recorded... The experiment [was] undertaken...in the belief that it would reveal the essential fundamental knowledge for the [goals of this program]. (Finegan, 1928, pp. 391-392)

Apparently the initial results of the study were encouraging. Saettler (1990) reported that eventually 250 educational films were produced as part of the Kodak project. Unfortunately, the deaths of George Eastman and Finegan combined with the depression to bring to a halt the Eastman Kodak

Company's film production projects. Eventually the entire stock of film negatives was donated to the University of Chicago.

Another early examination of the motion picture in science instruction was carried out in a study performed at the University of Chicago. For a large group lecture setting, it was determined that students receiving instruction from the motion picture attained a score of 67%. Those who were exposed to a lecture alone earned a score of 72% (the percentages were assumed to be scores on a post-test related to the content of the lecture and motion picture). Lemon (1922), the researcher, suggested that had there been narration present with the motion picture (this was a silent film), the scores received might have been reversed. In any case, the use of the motion picture as an instructional tool--or as one of a number of instructional tools--was supported by the findings of the study. In terms of efficiency alone, the use of a technician to project the film over a teacher to provide a lecture supported the use of the motion picture in terms of instructional efficiency. Also, from Lemon's perspective, a difference of five percent was not significant in terms of the scores achieved.

Davis (1923) made a direct connection between scientific literacy and technology. He examined in detail the use of motion pictures in science instruction. He summarized his findings to this end:

> In brief, the film can be used in the motivation and enrichment of ideas; it can be used in the promotion of creative thinking; it can arouse curiosity and it can develop the work spirit. The thing of most value in the film is its use tying up different techniques of teaching. The laboratory work, the reading of the textbook, class discussions, questions and problems can all be taught with more interest to teacher and pupil if teaching and learning are supplemented occasionally with good films, (p. 433)

To accomplish the goals he outlined, Davis made a strong case for higher quality films. In particular, he found that most films of the time were simply repackaged for academic use, with too much of the film devoted to entertainment rather than quality instruction. He offered specific suggestions as to engaging means of infusing the motion picture into instruction. At one level, he called for improvement in the quality of educational films; at another level, he made specific pedagogical suggestions that would make the most effective use of the technology in the science classroom.

Addressing the position of the Committee on the Reorganization of Secondary Schools, Davis made clear the uses of the motion picture as a

means of accomplishing their broad educational goals. The Committee was a nationally organized group sanctioned by the Department of the Interior and Bureau of Education to analyze the state of American education and identify areas for improvement. The motion picture provided a means of improving the quality of content knowledge gained. It also provided a means, when used interactively (i.e., with the teacher using the motion picture as a tool for making points and illustrating principles, rather than as a substitute for the teacher) of allowing the students to evaluate information and make judgements on the information presented.

The motion picture continued to gain wide acceptance as an educational tool throughout the 1920s. In an editorial titled "Education or Entertainment?" (School Science and Mathematics, 1929) the motion picture was included as one of many standard educational tools

> The school should provide the child with popular science literature, show him educational films and demonstrations, take him to museums, [and] include lectures and travel if possible...(p. 795)

By the early 1930s the use of the film in the classroom had reached the point where it was a standard piece of instructional technology. A 1933 article in School Science and Mathematics underscored this point as it detailed the availability of motion pictures suitable for classroom use. This change underscored a shift in the way the motion picture was regarded in the classroom. Rather than focusing on the hardware as early articles had done, or the pedagogy as the second generation of articles had addressed, the topic of discussion had moved to what pieces of software were suitable for classroom use. This reflected the overall acceptance of the motion picture as a part of classroom practice, and the need to help teachers make informed choices as to the film to be used in class to take advantage of the tool.

Special types of motion pictures designed to display scientific phenomenon were analyzed in detail in Edgerton's (1935) article on the use of high-speed motion pictures as a classroom tool. Here the intent was the use of the motion picture as a means of enhancing student understanding of scientific processes--in contemporary terms, part of developing scientific literacy. Similarly, special notice (SSMA, 1938) was made of a motion picture which

> will give teachers a clearer conception of the teaching aids available in this type of visual instruction. It will also present to students information of definite instructional value. (p. 603)

The motion picture's value in education had moved beyond the point where the complexity of the hardware was an issue; rather, the motion pictures themselves were seen as ways of developing skills and knowledge related to scientific literacy.

This shift was witnessed by an editorial change in the journal School Science and Mathematics. Rather than treating the release of new motion pictures as news articles, a series of reviews were offered of motion pictures suitable for science education, as was done with appropriate textbooks. This shift underscored the comfortable home motion pictures had acquired within the context of science education. The opinions offered were based on the experience of "science teachers in the [Columbia] Teachers College environment who have had considerable experience in the use of films." (Brown, 1939a, p. 197) The reviews addressed the quality of the films in terms of their scientific content, their suitability as teaching aids, and the technical quality of the films. It is interesting to note that the reviews addressed only sound motion pictures; the silent films, common only several years previously, were no longer in production, and were rapidly falling out of classroom use.

In a survey of materials and equipment for teaching elementary science (McAtee, 1939), motion pictures provided a significant contribution to the body of materials identified for classroom use. No justification or elaboration as to their need was offered; their use by this time was accepted pedagogy.

The first forty years of the twentieth century showed the birth of this technology in the educational world and its gradual institutionalization. As it became a standard part of the teaching practice, the interest among teachers moved away from the establishment of a pedagogy and training in the use of the projection machinery. Instead it focused on the increased availability of films themselves.

2.1.1 Transition to Mature Practice

By the end of the 1930s, the literature devoted to the use of the motion picture in the classroom had passed through three distinct phases. In the beginning, the literature was focused on the hardware. In the second phase, documentation investigated appropriate pedagogy for the use of the technology. Finally, in the third phase, the technology had achieved a permanent place in the classroom, and the majority of the documentation

produced at this point made teachers aware of appropriate software for infusion into the classroom.

The Second World War provided a new impetus for the use of motion pictures in the science classroom. The success experienced by military trainers was not lost on science educators. The efficiency of large scale--and standardized instruction--made for an attractive combination. In the field of science education, government produced films were again promoted for use in science education. The purpose of education had expanded to include a degree of military preparedness (or at least strong empathies) as shared by Stewart (1942; see also School Science and Mathematics, 1943). In a description of a series of films designed to "speed up training of defense workers," (pp. 705) their application for science education was noted as an additional advantage:

> Many of these films may be used to advantage in science and mathematics classes. Films such as Steel Rule, Micrometer,...and Cutting a Spur Gear not only facilitate the regular work in physics and mathematics but also demonstrate the relationships between these subjects and the work in industry and war production.(pp. 705-706)

Again we see the connection between the purposes of science education at this time and the use of the motion picture to facilitate this goal. Science education, it will be recalled, had recently found its voice in the words of the National Society for the Study of Education (NSES, 1932):

> This Committee, then, recognizes the aim of science teaching to be contributory to the aim of education; viz., life enrichment. It recognizes the objectives of science teaching to be the functional understanding of the major generalizations of science and the development of associated scientific attitudes. (p. 57)

Several trends marked this post World War II era. These trends each helped to bring about the goals of scientific literacy and the means by which the motion picture could contribute to its accomplishment.

The first of these trends was represented by the increased availability of film. Numerous film repositories came on line. These, combined with growing recognition of available titles for teaching, helped cement the role of the film within science teaching. In addition, experiments in the format for films--such as film loops--provided another avenue for the motion picture as a means of developing scientific literacy.

Sharing an opinion piece on the utility of the motion picture as a part of the science classroom, Schreiber (1944) identified the ongoing needs of teachers in terms of infusing motion picture technology into the classroom. Two areas he suggested were lacking in teacher training. One was a lack of awareness of the value of the film in science instruction; the other was teachers who recognized the value of film, but were lacking in specific knowledge as to how to use them.

Throughout this era, the motion picture as part of the experience in the classroom was confirmed as a mature classroom technology. That the authors of the Forty-sixth Yearbook recognized the motion picture as a part of a student's standard classroom experience reflected its stable place as a classroom tool.

2.1.2 Improving Pedagogy with Technology: The Film Loop

Further refinements in the pedagogy associated with the motion picture were part of this era. Walter, Brenner, and Kurtz (1957) examined the use of repetition and questioning as a tool to make more effective use of films in the science classroom. Though the significant effects of the study were small, it was determined that in the study's experimental conditions, there was a tendency for boys to be more successful than girls through the use of motion pictures as an instructional medium. Significant in terms of this study was the drive to achieve increased use of the motion picture. Films were already an important part of the curriculum, according to the Walter, Brenner, and Kurtz (1957) investigation, so the question becomes what can be done to make their use more effective? How can student learning of science (i.e., scientific literacy) be enhanced? Other studies continued to seek more effective means for the use of the motion picture in the science curriculum.

The curriculum projects of the 1960s brought about an interesting application of the motion picture. Over thirty years after the introduction of the "talkie" as the standard approach for commercial and educational films, the film loop found a place in the science curriculum.

Rather than attempting to duplicate an entire lesson, or develop more than one idea in a lengthy film, film loops were single-concept artifacts. The film--a continuous strip--was enclosed in a cartridge for ease of operation. With the need for threading and rewinding the film eliminated and a simple set of controls for the teacher (which included the ability to stop the film loop in action, with minimal damage to the film itself), the film loops

provided teachers with a means of better using the moving images to develop concept knowledge. The Physical Science Study Committee (PSSC) physics program is notable for the extensive library of physics film loops developed under its auspices. Such topics such as vector addition and the collapse of the Tacoma Narrows Bridge (notoriously difficult to duplicate in the classroom) were among the many titles available.

By the mid 1970s, the strong bond between the motion picture and science instruction was further cemented by the publication of the American Association for the Advancement of Science's (AAAS) Science Film Catalog. It made every attempt to serve as a comprehensive directory to all films that had a worthwhile role in science education. The link between scientific literacy and the value of the motion picture as a teaching tool was made implicit by the author of the catalog's forward: F. James Rutherford. At the time, Rutherford was the chairman of the science education department at New York University and the president of the National Science Teacher's Association. (Within the decade, he would serve as one of the primary authors of Science for all Americans, one of the preeminent statements of scientific literacy of the current era.)

In his catalog introduction, Ruterford (AAAS, 1975) made the following statement:

> Now thanks to the AAAS...we have in a single source a film catalog that is comprehensive, that uses standard library referencing, and that is usefully categorized. I am confident that more thoughtful use of science films will result; if so, our students as well as ourselves will have been well served. (p. vii)

Further remarks connecting the film with the goals of scientific literacy were found in the preface.

> Helping this public [defined as the school and college student population and their teachers] to understand the sciences and the scientists as well as the social and political ramifications of science and technology is an important function of the communications media. Through this Catalog we hope to increase the use of science films and, consequently, to increase the public's understanding of science. (AAAS, 1975, p. ix)

The connection between the use of this technology and the goals of scientific literacy was made abundantly clear in the previous set of remarks. The goal of producing a scientifically literate citizen was stated in the remarks of the preface.

Another important transition was made clear by the scope of the Science Film Catalog, especially when contrasted with early works such as the Gages' (1914) Optic Projection. The focus was no longer on the hardware; rather, the software that supported the instructional goals became the primary issue for science teachers. That few volumes similar to Optic Projection were produced in the move to videotape spoke volumes about the simplicity of the newer technology and of the comfortable status the motion picture (and it successor the video tape) had assumed in the science classroom.

2.1.3 Transition to Video

By the 1980s, the motion picture, in the film format, was a mature and entrenched part of the culture of the science classroom. Changes since the 1980s have related to the format of the technology, which have contributed to its current role within the science classroom. The notable movement has been away from the motion picture as film and into new technological formats: videotape and videodisc. These newer versions of the older film technology also offered some advances in terms of classroom application. The video tape offered lower costs and greater flexibility of use, especially with teacher and/or student created artifacts. The videodisc offered high quality, rapid access to images, and the potential to interface the software with the computer.

2.1.4 Videotape

Videotape provided a low cost alternative to motion picture film. It also had a built-in flexibility which motion pictures did not possess to the same degree: a classroom teacher could create his or her own videotapes, or simply record a television broadcast for later use in the classroom.

Videotape was available by the 1950s. With the increased availability of video players, commercial video tapes, and video cameras, the motion picture entered an entirely new phase in classroom practice.

By the end of the 1970s, the motion picture—in the film format—had begun to be replaced by a new format: the videotape. This change allowed several new options in the classroom experience with technology. The first gave the teacher greater power to capture images personally and use them in the classroom. The second offered the chance to capture broadcast programs and infuse them into their curriculum. Finally, the relatively lower cost of

the hardware and software made the videotape more available for all concerned.

Serving as a link between science teaching practice and using technology in the classroom, Reynolds and Barba's text Technology for the Teaching and Learning of Science (1997) provided a guide for those who wished to examine current science classroom practice with the use of technology.

Reynolds and Barba's (1997) suggested uses of videotape moved beyond simply showing videotapes to students. They saw technology as a means of enhancing science process skills. To cite one example related to videotape, videotape and the videotape recorder were suggested as means of making observations and collecting data. The authors urged for a number of reasons the use of video in the science classroom.

> Video-based instructional activities enhance science teaching and learning in that they (a) allow students to observe events in the natural world that are normally too quick, too slow, or otherwise too difficult to observe, (b) supply visual representations of science phenomenon, (c) permit students to reflect upon their observations, (d) provide verification of students observations, and (e) encourage students to hypothesize. (Reynolds and Barba, 1997, p. 71)

Moving from the points identified above, the use of video in the classroom developed science process skills in these ways:

> The very act of using a video camera to record observations or preserve an event results in your focusing attention on the subject. This focused attention occurs when you are deciding what to videotape, when carrying out the camera work, and finally, when viewing the result.(Reynolds and Barba, 1997, p. 71)

The video camera offered the means of developing the observation process skill:

> Recording an event on tape allows repeated observations. By viewing a videotape, not once, but several times, students can confirm the details of an observation and usually discover details that [had] previously not registered with them. (Reynolds and Barba, 1997, p. 71)

The level of student engagement in the activity--a worthwhile goal in the context of hands-on/minds-on science instruction--can be enhanced by the use of videotaping.

> Videotaping gives students control over time: action can be slowed or accelerated through slow motion or time lapse photography techniques, allowing students to study specific details of changes that have occurred, or to dramatize the change process. (Reynolds and Barba, 1997, p. 71)

The applications of videotape in science education remained similar, in many ways, to the original suggestions for the use of the motion picture in science education. The focus on observation, on bringing experiences to students, and observing what was impossible to duplicate in the classroom were all reasons offered for the use of the motion picture as a classroom tool. An advantage of videotape over the film, however, was the ease of producing and capturing one's own set of images. Production costs were essentially zero; once the images had been recorded, they were ready for playback.

The simple nature and adaptability of the videotape provided another area of suggested use by science teachers.

> The use of video cameras, or videotapes is adaptable to a variety of instructional approaches and settings--individuals, small groups, and large groups; prescriptive, guided, and independent use; for demonstration, exploration, and experimental investigating; in the classroom, outdoors, on field trips, and for home assignments.(Reynolds and Barba, 1997, p. 71)

A number of creative suggestions for classroom practice were identified. An applications such as using a video camera to create a close-up image of a chemical reaction, both to allow students to see it better and to make a permanent record of the event, was typical (Reynolds and Barba, 1997).

Moving from methods text to the classroom, Michael and Brinkhorst (1991) shared a number of their classroom experiences using a video camera in an article in The Science Teacher. They made use of the camera's data collection strengths to structure a number of student activities to promote and clarify student understanding of physical phenomenon. In particular, using the ability of the video images fixed rate of recording allowed measurements that were previously qualitative to become quantitative.

One example of using the ability to record events on videotape was related by Park and Lamb (1992). In one sense, their use of video brought the use of the motion picture “full circle” with the earlier applications, in that they were using selected vignettes from commercially released motion pictures. Their application of the video images was to have students analyze

the situation depicted on the videotape from a point of view informed by the laws of physics. One particularly amusing episode involved students using scenes from the movie Superman II to estimate the speed of Superman as he conducted a rescue of a falling child.

2.1.5 The Videodisc

The videodisc entered the science classroom during the 1980s. In its simplest form, it was used in much the same fashion as a motion picture, by simply showing a motion picture or an educational program all the way through.

The technology, however, allowed for a number of advances over both film and videotape. A vast quantity of information--over 55,000 individual images--could be stored on a single disk; the images could represent either single discrete frames or one of a series of frames in a moving image.

Related to the nature of the storage, access to the images was virtually instantaneous. The time spent waiting for suitable footage to be advanced on the reel or film or the videocassette was eliminated. This point was emphasized by Scaife and Wellington (1993):

> A laser vision disc [videodisc in US terminology] for example...can store up to 55, 000 still pictures or 37 minutes of video footage on one side. A disc is far more than a video cassette in this context, largely because of its direct and fast access using digital location of data which can be managed by the computer. (p. 70)

The videodisc was typically used in two different approaches. The use termed “Level I” put the instructor in direct control of the sequence of video images desired.

The “Level II” use of the videodisc made use of a navigation program built into the videodisc itself. This program helped to control the sequence of the video images. Ultimately, this form of the technology was used only occasionally, as the programming on the videodisc tended to be videoplayer-specific. By the late 1980s, the nature of the technology also made it ideally suited for interactive multimedia applications with a computer interface. In this format, a computer selected the sequence of images by a predetermined program, or in response to the apparent needs of the learner. This computer-controlled use of the videodisc was described as “Level III.” The merger of computer technology and videodisc technology are addressed in detail in Chapter 6.

The use of the videodisc as a tool in science teaching took off rapidly during the late 1980s. For use in the science classroom, Barron, Breit, Bouleware, Bullock, Bethel, Hoffman, Kritch, and Thompson, (1994) identified specific advantages associated with the use of videodisc. Movies and documentaries provided one application of the videodisc, an application of the technology similar to its previous incarnation as film and videotape. Applications more closely associated with the videodisc itself included instructional games, tutorials, visual databases, multimedia libraries, demonstrations, video report makers, and inquiry activities. Their study suggested that the fundamental structure of the videodisc technology lent itself to applications in teaching and learning which would benefit from the flexible and interactive nature of the software.

Other studies regarding the effective use of this technology appeared during the late 1980s and early 1990s. Similar to studies comparing the effectiveness of standard classroom instruction with that of the motion picture seven decades before, initial studies examined the use of the videodisc as a classroom tool.

In one particular application of the technology Muthukrishna, Carnine, Grossen, and Miller (1993) examined the use of the videodisc as a means of addressing students' alternative frameworks.[*] The videodisc, when used as part of a well-designed science curriculum, was found to change 92% of the existing alternative frameworks held by students. The flexible nature of the technology allowed the instructor to offer lessons that

> controlled critical curriculum design variables in presenting concepts...and provided immediate guided application [which] seemed to more efficiently eliminate alternative frameworks than those who used instruction time to focus on alternative frameworks exclusively.(p. 244)

When compared with a control group that did not make use of the videodisc as an instructional tool, the experimental group outperformed the control group. The videodisc, as part of a well-organized curriculum, helped students to address and conquer existing misconceptions.

* An "alternative framework" can be considered a student's misconception of a scientific principle. Typically these children display an understanding inconsistent with the accepted understanding of the phenomenon. A typical misconception is that the seasons are due to the sun being closer to the earth in the summertime, rather than due to the tilt of the earth's axis.

Findings by Hasselbring, Sherwood, Bransford, Fleenor, Griffith, and Goin (1987-88) would seem to confirm this. In a study examining the Level I use of a videodisc as an instructional tool, the gathered led to the conclusion that the

> gains found in the study were related to the instructional nature of the ... program and not to the novelty of the videodisc medium. Finally, it was found that even though the program had a positive effect on student achievement, the effectiveness of [the videodisc], like other instructional programs, is somewhat dependent upon the commitment and quality of the teacher using the software. (p. 151)

Other findings, such as those by Hofmeister, Englemann, and Carnine (1989) further confirmed that the videodisc could be an effective classroom tool. When used appropriately in the classroom, Hofmeister and his colleagues found that the videodisc helped in the following areas: in countering the fragmentation in the curriculum, by promoting instructional clarity, by the accurate use of terminology, by countering instructional vagueness (on the part of the classroom teacher), and by the careful sequencing of instruction.

Based on those principles of successful instruction with the videodisc, several programs of note were used by the early 1990s in classrooms at the elementary and secondary level.

Full Option Science System. The Full Option Science System, universally known by its acronym (FOSS), provided for the elementary teacher of the late 1980s and early 1990s a comprehensive classroom tool for science instruction. In addition to a set of hands-on science manipulatives, a set of ten videodiscs provided over five hours of information and experiences for the teacher to use as a part of classroom instruction. An exhaustive series of manuals provided instructional suggestions, as well as a comprehensively indexed (by bar code) set of videodisc images. As discussed in chapter 6, complementary computer software allowed for Level III use of the videodiscs by either students or teachers.

Profiled in the staff development program <u>Capturing Excellence</u> (Thompson, 1997), an elementary teacher made these remarks on her use of the <u>Science Essentials</u> (the multimedia component of FOSS) videodisc as an instructional tool in her science classes:

> I decided at this point in the lesson to use the laserdisc [previously a common name for the videodisc] to bring in a real life example for the

> children. I could have given them examples, or talked about examples, [such as] at the airport, or downtown Chicago to try to get that picture into their mind. But the laserdisc gives me accessible, easy to use, ways of bringing real life situations into the classroom for the kids to take a look at. So the picture in their mind is there as they begin to work with the materials in the class. I had used the teacher's guide ahead of time to find this particular segment. It was readily available for me to use with the barcode. I used a light pen, then scanned it across the barcode, then I could access the information easily. (audio track 4, frames 05857-07387)

She provided further elaboration as to why the videodisc was her medium of choice for certain activities.

> I like laserdisc technology because I can control which brief segments to use and they can both enhance and clarify my lessons. I can efficiently access brief segments to clarify and enhance my lessons. There are times during the lesson when I like to use the remote and freeze frame. This allows me to go into greater detail. (audio track 4, frames 15857-16540)

Windows on Science. Optical Data corporation's video disc products such as Encyclopedia of Animals (1987) provided another example of a comprehensive videodisc designed for elementary classroom instruction. Related to the point developed previously, that the videodisc is an effective tool only within the context of effective pedagogy and curriculum, the Encyclopedia of Animals package provided a user-friendly interface (similar to that of the FOSS program). A set of annotated barcodes were supplied to make selection of appropriate footage a simple matter. In terms of the curriculum, the series was developed as a "video textbook" which was designed to provide a highly structured series of images for students. The consistent theme of "fitness," in a Darwinian sense, provided the overarching structure for the instruction (Optical Data Corporation, 1987). For an existing biology curriculum, the wide variety of video clips were designed to help students gain an understanding of the concepts covered within the school's curriculum. The ease of access and complete annotations made it a simple matter for teachers to infuse videodisc technology into science instruction.

The series benefited from a number of investigations into the utility of the approach. A series of studies conducted through the University of California (Irvine) found the materials to be helpful in several different areas (Department of Education, University of California-Irvine, 1993):

> The studies all used reliable assessment procedures to examine the implementation and outcomes associated with these bilingual science

> videodisc programs. Although they were conducted with varying groups of student populations and in different sites, the studies demonstrated striking similarities. Large positive effects associated with the use of the program were consistently found in student attitudes. These included substantial gains in the attitudes towards science of male and female students. Positive effects were demonstrated on students' knowledge in science based upon science achievement test scores. (p. 1)

Based on these findings and others (Denham, 1991, McWhirter, 1991, and Anthony, 1992), empirical evidence supporting the use of the <u>Windows on Science</u> programs has helped to move this technology into the classroom.

While the program was conceptually sound and showed that it could be an effective component of a science program, some resistance to the use of <u>Windows on Science</u> appeared. The common point of contention was that the series was perhaps <u>too</u> structured. While in some senses this was an advantage--inexperienced teachers or teachers with little content knowledge were found to be well-served by the program (Denham, 1991)--others found the structure and heavily scripted lessons to be frustrating. The lesson to be gained from these insights was that technology should not merely automate instruction, it should emancipate it as well.

National Geographic Video. Not all videodiscs were designed as components of a larger science curriculum. The National Geographic Society's <u>Born of Fire</u> (1983) was one such example. This approach was similar to the uses of motion picture in the classroom of the 1930s. Rather than providing the entire act of instruction, the video provided a single, coherent set of images to support classroom instruction needs. As the videodisc medium was rather expensive, the single use approach proved to be fairly uncommon, but it provided an excellent compendium of visual images for students to examine.

Science Sleuths. Midway between a single topic videodisc and an entire series of videos, the <u>Science Sleuths</u> provided a viable alternative. The expense of the videodisc was diffused in that several episodes were included, rather than a single program as in the National Geographic approach. Focusing on the process skills of science more than a single area of content, the <u>Science Sleuths</u> videodisc was comprised of 13 separate episodes. Consistent with 1990s views on scientific literacy, the focus was on problem solving skills and on student understanding of the "use of scientific knowledge, ideas, and inquiry processes" (National Research Council, 1996,

p. 52) and "providing opportunities for scientific discussion and debate among students." (NRC, 1996, p. 52)

Interactive Frog Dissection. At the secondary level, the dissection of animal specimens has long been standard practice in biology classes. To diffuse opposition surrounding the use of live specimens--ethical and financial (Straus and Kinzie, 1994)--an alternative was created in the form of an interactive videodisc on the topic of frog dissection. One advantage cited by a biology teacher, making a comparison between the videodisc and previous motion picture representations of the dissection experience was

> interactive video...can provide high quality video...with greater interactive capabilities than the film-based methods previously used in anatomy instruction. (Straus and Kinzie, 1994, pp. 398-399)

Investigation of the use of the videodisc as compared to an actual dissection experience led to several conclusions. Related to the quality of the learning, Straus and Kinzie (1994) found that data supported the position that videodisc-based instruction was as effective as an actual animal dissection in terms of the content knowledge gained. Interestingly, in terms of attitudes toward the value of dissection, those students who participated in dissection, over time, reported that their regard for the value of the dissection increased; those who participated in the videodisc-based dissection reported that their perception of the value for an actual dissection decreased with the passage of time. The authors suggested that this effect was likely due to the “subjects’ preferences for selecting the same instructional method that they used in this study in the future.” Straus and Kinzie, 1994, p. 401)

In the physical sciences, a number of videodiscs were available as well by the middle 1980s. Some of the products were simply classic education films produced in a new format; others were new productions designed to make use of the flexibility of the new technology (Kirkpatrick and Kirkpatrick, 1985, p. 401).

The Puzzle of the Tacoma Narrows Bridge Collapse. A videodisc which for many in the physical sciences defined the advantages of the technology for the classroom was <u>The Puzzle of the Tacoma Narrows Bridge Collapse.</u> Produced in the early 1980s, it was the first videodisc created for use by physics teachers. Combining an historical examination of the bridge's construction and its fascinating collapse with an investigation into the characteristics of waves and structures, the program also offered the student three paths by which to view the information, depending on the level of sophistication desired (Kirkpatrick and Kirkpatrick, 1985). Through a series

of experiments carried out on models of bridges, the images engaged the student at a high level, focusing on the ability to evaluate data and draw conclusions from the findings.

3. LINKS TO SCIENTIFIC LITERACY

When observed through the lens of social psychology, the tendency to engage in certain behaviors is related to expectations for success in that behavior and the perceived value of engaging in that behavior.

The use of a technology such as the motion picture as a component in a science course relied on several issues. The teacher must have recognized the utility associated with the use of the motion picture. The teacher must have had some expectation of success related to the use of the technology. The teacher must have had evidence that the cost of learning to use the technology is worthwhile and the teacher's level of interest must have been sufficiently high to make the use of the technology worthwhile (Eccles (Parsons), 1983).

The issue of the perceived value—the utility of the technology--informed the overriding reason for infusing the motion picture into science instruction. The use of technology provided the teacher with an enhanced means of achieving scientific literacy. The sophisticated tool represented by the motion picture offered an engaging and effective means of helping to achieve the goals of scientific literacy.

Early in the century, with the Nature Study approach a strong influence in science education, it was easy to see how a motion picture could be used to advocate the values inherent in the Nature Study approach. A notice in <u>School Science and Mathematics</u> in 1931 implied much about the progress of developing educational films. A motion picture profiled in an article was lauded for the perspective it could bring to the classroom. The topic of the film was the use nature could be for man. The title of the article --"New US Film Shows Ways In Which Forests Serve Man" (p. 394)--implied more about the scholarly thought with regard to science education at the time than the actual content of the film. The motion picture reflected the views associated with the Nature Study movement--and with it a tendency to see the world only in terms of how it supported human needs--and empathy for the agricultural life style promoted by Nature Study advocates. Brodshaug and Strayer (1932), reflecting on the suitability of the motion picture for teaching topics associated with the Nature Study curriculum, found further

support for the purposes of the Nature Study movement through the use of the motion picture.

> In the past, the excursion has been looked upon as the prime device in nature study. The inadequacy and impracticality of excursions are among the chief reasons that elementary science has, in many instances, failed to attain the objectives set up for it...
>
> It is our belief that sound pictures will stimulate the imagination, which may lead to a desire to investigate in greater detail the ideas that have been brought out by the picture...(p. 361)

In the early part of this century, in the text of the Thirty-first Yearbook, the purpose of science education was defined by the National Society for the Study of Education

> to be contributory to the aim of education; viz., life enrichment. It recognizes the objectives of science teaching to be the functional understanding of the major generalizations of science and the development of associated scientific attitudes. (NSES, 1932, p. 57)

The use of the motion picture reflected the position stated in the Thirty-first Yearbook. The motion pictures of this era were primarily vehicles for bring content knowledge to students, helping to bring the information needed for students to develop their understanding of the "major generalizations." Noted Hunter (1934),

> The motion picture also has other definite values than that of motivation. It takes the place of the field excursion and the visit to the manufacturing plant. For the purposes of explaining and summing up the applications of science in manufacturing, mining, engineering projects, fisheries, and the like, it is unexcelled, provided the legends are made for the age level at which the film is used. (p. 301)

Statements paralleling those of Hunter were made by Rulon (1933) in his book The Sound Motion Picture in Science Teaching. In this book, he profiled a number of investigations into the use of the motion picture as a tool in science teaching. In the appendix, the instrument used to gauge student learning displayed an educationally simplistic point of view: true/false and multiple choice questions related to the content knowledge of the films used in the study form the instrument by which student learning was measured. Though the questions were knowledge-level questions and asked the students to offer nothing deeper, the findings supported the use of the motion picture as a tool in science teaching.

The Forty-sixth Yearbook was quite direct in its advocacy of technology. "Motion pictures and slidefilms may be used to achieve many of the objectives of science education." (NSES, 1947, p. 57) The document identified issues related to both suitable instruction and curriculum concerns. An extensive range of instructional possibilities were offered by the NSES (1947).

> In certain situations the motion picture...may be developed as a self-contained unit, embodying motivation, concept teaching, review and summarization, activities, and follow up work. (p. 102)

The limitations of the technology were recognized as well. The inflexible nature of the motion picture was, in particular, called to task.

> ...the motion picture has some very definite limitations as a visual aid. It is inflexible in that the teacher cannot alter the time allotted to any one scene in the motion picture. In contrast, the film strip is highly flexible in that the teacher can spend one minute or ten on each frame, according to her conception of relative importance. In addition, she can, if she wishes, turn back the strip to any frame to which she desires to make additional reference. Also, the slide film has obvious possibilities as a teaching medium, since it allows for active participation and discussion on the part of both children and teachers, whereas the motion picture limits such active participation since the presentation of the subject matter is fixed and beyond control of the teacher. (NSES, 1947, p. 103)

Forty years later, advances in technology rendered moot these critiques of the motion picture. But at the time these were genuine concerns related to how to best use the technology in the classroom.

Instructional issues related to the use of the motion picture were not addressed in the Fifty-ninth Yearbook (NSES, 1960). By the late 1950s, the needs of curriculum and instruction had apparently resolved themselves in terms of the use of motion picture technology. Too, the technology had remained fundamentally the same for the thirteen years between the publication of the Forty-sixth and Fifty-ninth Yearbooks. What was present was a statement outlining conditions necessary within schools such that teachers could make optimum use of the technology. Indeed, all manner of audiovisual aids were addressed in a single paragraph.

> Rooms should be equipped with a projection screen placed in a permanent location. To simplify "plugging in," the speaker-cable conduit should extend the length of the room. Darkening facilities,

chalkboards, tackboards, display cases (one visible from the corridor) are minimum requirements. (NSES, 1960, p. 237)

By the 1960s, with the dominant view of science education encapsulated in the term "scientific literacy," films were no longer considered so much an agent of educational efficiency. Rather, the use of the motion picture was to assist in the development of thinking skills, process skills, and problem solving skills.

The impetus for using motion pictures was still to teach science "better." The definitions that informed "better" teaching had evolved from a focus on content knowledge--which showing a film as a substitute for a teacher's lecture accomplished admirably. By the 1960s, with the use of single concept film loops, and the 1990s, with the videodisc and video tape allowing the teacher the ability to craft his or her own set of video images, the images were used to develop thinking skills.

As an example of the thinking skills--referred to as "Habits of Mind" in Benchmarks for Science Literacy, the development of more sophisticated observation and critical response skills were essential components directed toward the achievement of scientific literacy. Using the skills of observation to make use of a video image and then evaluating the quality of the information contained in the video represent some examples of how this medium was used by the 1990s. Using the information presented in a film or videotape, developing inferences, and drawing conclusions with the information presented represented a more sophisticated use of the technology than simply relying on it for content information. And the increased sophistication was consistent with the evolving requirements of what constituted scientific literacy.

4. REFLECTION ON THE INFUSION OF TECHNOLOGY

This chapter served to describe classroom practices associated with the motion picture as a means of achieving scientific literacy. As the twentieth century progressed, several trends related to the use of motion picture technology in science education became evident. Three categories suggested themselves from classroom practices examined:

1. Development of interest and focus on the hardware.
2. Development of appropriate pedagogy, and

3. Dissemination of software as the use of technology enters a mature state. (King, 1999a; 1999b; 2000)

Pioneers in the use of the technology provided the first step in this sequence. These individuals were the first to make application of the new technology in a classroom situation. The focus on the hardware--the machinery used to project the images--represented a continuation of the first phase in the literature related to the use of technology. It typically provided insights for those in the second wave of technology infusion.

Developing appropriate pedagogy was a process that continued throughout the presence of motion pictures in the classroom, from their earliest incarnation as silent movies to their more recent expression through videodisc technology.

As the technology matured, research articles and investigations examining pedagogy related to use of the technology declined in frequency. By this point, the motion picture had "arrived" as a standard part of the teacher's repertoire. Interest at this point among classroom teachers was more in terms of the type of software available for their classroom practice. The reviews offered by Brown (1939a, 1939b, 1939c, 1939d, 1939e, and 1939f) in <u>School Science and Mathematics</u> provided evidence of this focus.

This process repeated itself in a similar fashion with the adoption of first the videotape and then the videodisc as standard means of classroom instruction. Early "pioneers" clarified the use of the technology in the classroom. Their initial work with the videodisc informed the standard practice of the day.

A trend of significance related to the use of the motion picture reflected changes in the pedagogy and the development of "thinking skills" described in the recent curriculum standards for science education. Early in the century, the motion picture was compared to the human teacher to determine which was more effective. In experimental studies examined from the 1920s, either a human or a machine offered the entire lesson. By the 1960s the issue had moved away from the use of the technology to do all of the instruction; rather, the technology and the teacher worked as partners, with the teacher selecting appropriate images for a more selective use. The days of the motion picture providing the entirety of the instruction had passed. Park and Lamb's (1992) use of motion picture images to develop thinking skills in physics may not have met Thomas Edison's goal of "100 percent

efficiency," but it did reflect a deeper thinking process and a classroom of engaged students, an outcome of perhaps greater significance.

5. SUMMARY

The motion picture remains a key classroom tool for science teachers. Videotape and videodisc--the current manifestation of motion pictures--are in nearly every classroom.

The motion picture provided first and foremost a means of bringing the world at large to the science classroom. To this end, it satisfied many of the content-oriented aspects of scientific literacy during the early part of the twentieth century. Advances in the technology allowed for the thinking, learning, and inquiry skills promoted in the late twentieth century conception of scientific literacy to be better addressed.

A trend of introducing the hardware to the classroom, developing effective pedagogy, and then bringing the trend to closure with the dissemination of available software was evident as the classroom uses of the motion picture developed.

The infusion of educational radio into the science curriculum exhibited similarities to the motion picture. The information presented in Chapter 4 will examine both the similarities and the differences as another technology assists teachers in achieving scientific literacy.

Chapter 4

Radio in the Science Classroom

Afield With Ranger Mac

> It is axiomatic that your local radio station manager will carry any educational program offered by his particular network connection if enough people demand the program in writing. Thus almost any wide-awake science or mathematics teacher may take steps to encourage some good radio listening in his community. It seems that...every teacher is concerned with radio education (Neal, 1945, p. 155).

Looking back from the vantage point of over a half-century, those words seem somewhat quaint. Perhaps because of the ubiquitous nature of radio it hardly seems revolutionary enough that "every teacher [ought to be] concerned with radio education." Perhaps, though, the near universal presence of radio *should* concern all teachers with the challenges and needs of being able to teach with the technology of radio. The next chapter will seek to describe the enthusiasm for radio instruction in the sciences during the middle years of the twentieth century, and to examine how it helped to shape a conception of scientific literacy during that time.

1. BACKGROUND: DEVELOPMENT AND ADOPTION OF THE TECHNOLOGY

Much as with the debate as to what qualified as "educational" with respect to the educational use of television a generation later, the issue of what sort of broadcast fell into the category of educational is of interest with respect to the use of the radio as well. On one level, all types of broadcasting, beginning with the 1920 Harding-Cox election returns on

Philadelphia's KDKA radio station, to other news and musical broadcasts, can be considered instructive on one level (Lindop, 1953). To avoid falling into the trap of "all radio is instructional," the focus of this chapter was on the use of radio in ways that specifically supported science instruction. This directed the study to an examination of programs such as Afield with Ranger Mac, broadcast during the 1930s by the Wisconsin School of the Air. Programs like this helped to develop an understanding of how the use of the radio influenced the goals of scientific literacy.

1.1 The Development of theTechnology

The development of the theory and the original hardware associated with the radio was accomplished by Guglielmo Marconi, the Italian physicist who shared the Nobel Prize for this work in 1909 (Wu, 1999). While the theory underlying the concept of radio was correspondingly complex during its day, the materials needed to create a radio receiver were fundamentally simple: a coil of wire, a length of wire for an antenna, another length of wire for the ground wire, a diode, and an earphone. These fundamental components are still the essence of all radios in use today, and the building of crystal radios is still part of many science curricula and the pursuit of many home hobbyists (Xtal Set Society, 1999).

1.2 Public Use of the Technology

> In popular history outlines of twentieth century events, KDKA's announcement of the 1920 presidential election results is usually listed as *the* beginning date of United States radio broadcasting...A small but eager audience was prepared to receive any broadcast offered, and occasional broadcasts rapidly evolved into regularly scheduled presentations (Barfield, 1996, p. 3).

The beginnings of commercial and educational broadcasting would seem to overlap. The beginnings of commercial broadcasting and of educational broadcasting claim the same beginnings.

The movement of the radio from experimental device constructed by the listener to an essential part of the American home experience. In Barfield's (1996) Listening to Radio, numerous individuals recount their first experience with a radio as a youth during the 1920s as well as other experiences with radio as the family gathered around a wireless set during the heights of the depression.

And the numbers grew. From the homemade radio receivers of the 1920s, by 1927 consumers spent millions of dollars on radios. As early as 1924, Arthur Atwater Kent's Atwater-Kent radio Company spent nearly $500,000 on advertisement promoting the new technology (Radio History Society, 2000), underscoring the growth of the media.

1.3 Educational Advocates

> To the teacher of today talkies, radio, and television may seem costly, cumbersome, and strange as instruments of instruction, but tomorrow they will be as common as the book and powerful in their effect on learning and teaching.... What about radio in the schools today? It is still embryonic but it is growing. Our best educators no longer call it a fad or brand as mere enthusiasts those who advocate its use....If it can add as much as five percent to the effectiveness of our schools--and that is a most conservative estimate--it is worth $100,000,000 a year to the educational enterprises of our various states and communities (Morgan, quoted in Darrow, 1932, p. ix).

Advocates for the instructional use of radio were numerous and vociferous. By the 1940s numerous studies had taken place to document and investigate the usefulness of radio as an instructional tool (Atkinson, 1942; Darrow, 1932; Reed, 1943; Himmelreich, 1938; Wisconsin Research Project in School Broadcasting, 1942). The Taylor-influenced call for instructional efficiency can be inferred from the quotation by Morgan above; it is complemented well by this perspective—one that resonates particularly well in comparison with the today's zealous advocates of the computer in the classroom:

> During the last ten years there have been some radio enthusiasts who assumed quite blithely that radio was an educational panacea, that radio listening in a classroom would suddenly bring about miraculous educational changes in pupils. Some of the claims made for radio education have been just as fantastic and just as ridiculous as the claims set forth by radio networks of six, eight, and ten million listeners to their daily broadcasts (Woelfel and Reid, 1945, p. 22).

Though those comments made for interesting headlines and served to polarize discussions, there were a number of important studies that examined the role of radio in teaching and created the enthusiasm for the use of the radio in the classroom. Key among these studies were investigations taking

place under the leadership of faculty members at the University of Wisconsin.

One of the more comprehensive examinations of the use of radio as a teaching tool occurred through the auspices of the University of Wisconsin. As a part of Wisconsin's School of the Air, a careful analysis of teaching with radio was undertaken during the late 1930s. Their experience with radio instruction led to investigations in these four areas of interest:

> Experience both in Wisconsin and elsewhere indicated that radio, as a means of communication and with the limitations imposed by the nature of the medium, can be used profitably in the classroom with one or more of the following objectives in view: (1) to give direct instruction in certain limited areas of the curriculum; (2) to demonstrate teaching methods and so perform a supervisory function; (3) to stimulate desirable responses and activities; and (4) to supplement or enrich classroom instruction by providing educational materials not usually available, especially in smaller schools. (Wisconsin Research Project in School Broadcasting, 1942, p. 4)

Levenson (1945) argued similar issues in behalf of the instructional use of radio. One point that would resonate with readers several decades later is the view that using radio in the classroom can help to integrate the learner's experiences. Specific programs noted by Levenson included <u>American Crusader</u> and <u>Let the Artist Speak.</u> The broad scope of these programs and their use in the classroom helped to bridge the knowledge between disciplines and helped students to achieve a richer understanding of the meanings shared by various disciplines. Stated Levenson (1945): "The meanings acquired in mathematics class related to those of the physics laboratory." (p. 11)

> Teachers who have used radio have freely expressed opinions on the value of radio in their work. It is a healthy sign that the majority of opinions are not colored by overenthusiasm nor by exaggerated claims for the use of radio (Willey and Young, 1948, p. 22).

That value, as reported by Willey and Young (1948) and confirmed by Carpenter (1939), served primarily to enlarge the student's experience beyond the four walls of the classroom. As was advocated with the motion picture several decades earlier, the primary value of the technology was to adjust the relationship between the student, space, and time, to bring to the classroom opportunities that would not be otherwise possible.

Himmelreich (1938) addressed some of the broader policy level concerns for the use of radio in instruction. In particular, he identified for the teachers of his acquaintance the need to develop effective instructional strategies with radio and the national level need to organize and finance educational broadcasting.

With respect to the teaching of science with the radio, Neal (1947) had a number of important points to make, paralleling those of Himmelreich. First, he cited the need for science-related broadcasts during the school day, so that they could help to enrich the science learning experience for the students. The second issues he offered for broadcasters to consider related to the need for long-range planning with respect to science-related broadcasts. In his own words:

> There is a need for some group—the American Association for the Advancement of Science, the National Association for Research in Science Teaching, the National Science Teachers Association, or some other—to develop a long-term comprehensive plan which is organized in a way to give listeners progressive information and understanding of basic principles which are related to the lives they lead (Neal, 1947, p. 237).

The third component of his proposal was related to necessary staff development efforts—how to get science teachers to understand what was available and how to assist them in connecting it to their instruction. As the following section will relate, many efforts were directed to that goal of developing appropriate instructional strategies to use with radio instruction.

1.4 Instructional Findings

During the late 1930s, there was considerable amount of research effort devoted to learning what optimum set of instructional conditions should be associated with the use of the radio in the classroom. Foremost among these efforts were the efforts by the Wisconsin Research Project in School Broadcasting (1942), who carried out an extensive series of investigations across the curriculum to gauge the value of radio instruction in Wisconsin's classrooms. In general, the findings suggested that radio had an important place in the state's schools, particularly related to developing student interest among the subjects visited during the radio lessons.

Findings for the science lessons presented other issues for consideration. First and foremost, those that were implemented found some degree of success for the students in the radio-enhanced classrooms. These

classrooms, however, were not nearly as common as were those supporting the arts and social studies. Among the successful science education projects, these will be considered subsequently in the profiles on the broadcasts of Afield with Ranger Mac and the efforts of the Rochester, New York public schools.

2. THE RADIO IN THE CLASSROOM

As an instructional tool, the American mid West was chief among the regions of the United States in adapting the radio for instructional uses. Reed (1943) suggested that this was due to the long distances between the towns and communities of the Mid Western states; combined with active state university systems, many of whom experimented with non-commercial broadcasts during the first decade of radio's existence, offered an excellent means for public outreach and service.

The value of radio as an instructional medium seemed apparent to all during this era. Radio licenses issued to educational institutions numbered over 200 during the time frame 1921-1936, the year Frost's (1937) study ended. License holders for educational broadcasts were typically colleges and universities, but also included a significant number of high schools. The radio instruction movement even found participation from station KFLZ of Red Oak, Iowa, representing the faculty of the Atlantic Automobile School (Frost, 1937). While Frost pursued a fairly straightforward accounting of radio licenses and broadcast histories during the early years of the radio instruction era, it is interesting to note some descriptive statistics offered by the various experiences of these educational broadcasters. Over thirty percent of the stations were in operation for one year or less; over fifty percent of the stations were broadcasting for a period of two years; and nearly seventy percent of the stations issued licenses during this era were functional for less than three years. These statistics underscored the experimental nature of educational radio broadcasting during this era.

Sources of instructional material were available from three primary areas. Commercial broadcast stations and non-commercial (usually school district or university sponsored) stations provided the first two means of securing programming for the classroom. As the commercial viability of radio became more evident, Reed (1943) noted with some regret that the initial offerings on non-commercial stations were often lost in a battle with the emerging broadcast industry:

> Nebraska Wesleyan University unquestionably is the outstanding example of the determined fight of an American educational institution to maintain its air rights against encroachment on the part of a commercial interests. From the time of the organization of the Federal Radio Commission in 1927 until the WCAJ equipment was sold to WOW (Omaha)...the university was forced into numerous changes in channel, power, hours of operation, and expensive litigation in order to maintain its station signals on the air...Funds of Nebraska Wesleyan University were too badly crippled by the depression to permit ... the expenses involved in carrying on a continuous legal battle...in Washington DC. [T]he University Administration considered it better to sell the station. Thus, for less than the value of the equipment, WOW purchased the air channel rights of WCAJ...and another educational station was silenced forever (pp. 96-97).

Frost's (1937) account of the experience is identical. The brief existence of WCAJ was marked by quality programming, but also by the bureaucratic whims of the primitive federal radio commission. During its broadcasting lifetime, WCAJ was heard on seven frequencies, which both taxed listener loyalty, but also placed it in direct competition with several other radio stations. The final conflict with WOW, however, taxed financial resources to the point that the university elected not to pursue the battle. As such, the available science instruction on the airwaves during the radio era was produced through the remaining non-commercial stations.

Other radio stations found that relationships with commercial broadcasters could be more productive. Station WFAV at the University of Nebraska operated from the mid 1910s though 1927, providing instruction, both informal and for university credit, as well as news and farm reports. Eventually, collaborative efforts with station KFAB starting in 1925 allowed the university to broadcast coursework over the larger and more powerful commercial station. This arrangement was considered satisfactory to all parties in positions of leadership, for when WFAV ceased broadcasting in 1927, the relationship between KFAB and the university continued (Frost, 1937). Though the instructional mission has long since disappeared, the relationship continues to this day in the form of KFAB's highly partisan broadcasts of University of Nebraska football games.

The third means of radio instruction alluded to was the creation of unique broadcasts by students themselves. While this was relatively common for instruction in the languages and performing arts, it was less common in science instruction.

2.1 Classroom Use of the Radio

The primary growth of radio as an instructional medium took place between 1925-1935, with the entire era of radio instruction spanning nearly thirty years between the early 1920s and 1950 (Saettler, 1990).

The challenge of using radio as a tool for the teaching and learning of science was similar to other technologies. In the use of the radio, as in the motion picture, the technology was suited better to bring information to students rather than creating an environment in which a hands-on science activity would have taken place. A typical science teaching vignette described by Weibe (1945) made this point abundantly.

In preparation for the activity, the teacher identified a broadcast selected from a radio instruction manual that would support the study of chemistry. Based on the available broadcasts, a program on the processing of wool was selected (Weibe, 1945).

The teacher asked his class to brainstorm all the possible scientific processes that could be demonstrated though knowledge of how wool was processed. Using this activity as an advanced organizer, the students then listened to a broadcast on the topic of wool. All members of the class, teacher and students alike, recorded key issues from the broadcast in their notebooks. Following the broadcast, the teacher engaged the students in discussion of the content of the broadcast, in particular the applications of science to the processing of wool. Concepts such as solubility (in terms of solutions used to clean the wool) were suggested by students as a means of preparing the wool for processing into yarn. According to the narrative, students demonstrated a number of connections between the science they had been studying and the applications of those concepts in agriculture and industry (Weibe, 1945).

It is clear from this vignette that without the ability to preview the program being aired, the potential value of the broadcast is related in large part to the quality of the teacher support materials associated with the program. This concern was addressed by a number of instructional radio programs (Carpenter, 1934) and eventually was adapted for most uses of instructional television, in which instructional guides were issued in advance of the broadcast (cf. Iowa Joint Committee on Educational Television, 1953).

Other schools sought to make use of the radio in the classroom though different approaches. The Bartam High School in Philadelphia used the school's public address system to make radio broadcasts of importance available to the entire student body (Johnson and Hunn, 1940). Initial attempts at this approach were found to be encouraging. To make the process more adaptable, the school worked in cooperation with the RCA corporation to record radio broadcasts for eventual use in the classroom.

2.1.1 Program Profile: Afield with Ranger Mac

A program such as <u>Afield with Ranger Mac</u> provided important instructional assistance to the students of the state of Wisconsin. First, given the wide range of possible classroom experiences possible, from the well-conceived and carefully articulated (such as those in the city of Madison), to the less well organized, primarily agricultural in orientation classroom experiences present throughout much of rural Wisconsin, the ability to provide consistent and well-defined science content was important (Wisconsin Research Project in School Broadcasting, 1942).

To meet the needs of these disparate audiences, the focus of the program was on Nature Study and conversation. Teacher support was in the form of a manual that contained instructional objectives for each of the broadcasts, suggested activities, bibliographic material, and other instructional assistance (Wisconsin Research Project in School Broadcasting, 1942).

To examine the instructional advantages of the broadcast, control groups were arranged to cover the same instructional content during a similar time frame. Students in the experimental group devoted five minutes to preparing for the broadcast, fifteen minutes of listening to the broadcast, and then an additional fifteen minutes of discussion following the broadcast (Wisconsin Research Project in School Broadcasting, 1942).

Comparisons of a pretest-posttest scores in terms of knowledge gained and changes in attitude demonstrated no significant differences between the different groups. Examination of factors such as age, gender, intelligence (measured through an IQ test), and urban/rural residence likewise offered no significant differences. Subjective measures through a follow-up survey, however, suggested one area of positive potential for the radio experience in the science classroom: teachers liked the use of the material. The availability of material not otherwise available to students was likewise perceived as an instructional advantage, though no differences in learning were measured (Wisconsin Research Project in School Broadcasting, 1942).

2.1.2 Program Profile: WHAM in Rochester, New York

> I don't know what I would do without radio science. I might never have known how old the earth is. I am not allowed to listen to the radio for three weeks and I would rather not say why. But that will make me all the more anxious to listen to the radio after the three weeks are up...Sincerely yours, Oscar (Carpenter, 1938, p. 207).

The words of a seventh grade student offer testimonial to the experiences of science instruction via radio. The efforts of WHAM and the Public Schools of Rochester, New York represent an example of a local school district's efforts, rather than the state-level initiative attempted in Wisconsin.

The seventh grade students of the Rochester School District, through restructuring and realignment, were placed in buildings that normally housed K-6 students and lacked sufficient equipment to teach science in a manner consistent with the district's 12-year science curriculum. Beginning in 1933, however, the use of radio was introduced as a means of circumventing the lack of equipment in the classroom (Carpenter, 1934; 1939).

The school curriculum allowed for fifty minutes of science to be taught twice per week. The radio lessons lasted 30 minutes, with 20 minutes following the broadcast for discussion of the points made during the transmission. To accommodate the lack of instructional materials, the activities described in the broadcasts focused first on developing student interest, and then on encouraging independent study at home, using easily available household supplies (Carpenter, 1934). Beginning in February of 1933, some 1000 students in the Rochester district and surrounding communities tuned into the twice weekly broadcasts on WHAM (Carpenter, 1938).

Topics covered during the initial 1933 offering were consistent with the district's science curriculum. In fact, one of the key outcomes from the teacher's point of view is that more science content was often covered than during the previous years. Teacher comments such as this were representative:

> My lessons did not cover nearly as much material as do your programs. I could not get near as many important items in my lessons. They were more general in nature.
>
> Some work was done, but not as much as has been done since we have listened to the radio broadcasts.

> ...[W]e have always had science in our classroom, but not as thoroughly or as often.
>
> The rural teacher is limited by time in both the preparation of and the carrying out of science lessons. Therefore, only a small amount of time was spent on science previous to the use of the radio. The radio affords the teacher more time in such work (Carpenter, 1939, p. 301).

The question not addressed was the degree to which the radio-infused lessons influenced science teaching in most classrooms except in the most general terms. Allusions were made to an increase in quality and quantity of science instruction, but the precise nature of what that meant was difficult to discern. The implication from the comments above suggests that science was not commonly a part or the curriculum, of if so, it was a minor part of the experience. The radio apparently introduced a common and consistent level of instruction to the classrooms participating in the project. Using the radio as a key part of the instruction provided assistance to teachers as suggested by the statistic that 87 percent of surveyed teachers would perceive themselves as handicapped in science instruction of the radio programming were removed (Carpenter, 1939). The success, as measured from the teacher's perspective, worked hand in hand with the user-friendly approach taken by the creators of the broadcast. To ensure that the connection between student and broadcaster was optimized, a small group of students participated in the radio broadcast, giving the radio teacher visual cues as to how the lesson was proceeding (Carpenter, 1936).

Despite the fact that the students were primarily required to listen and take notes to a thirty minute broadcast twice a week, the discussions and independent investigations tried to involve as many students in the experience as possible. Student organization in the initial classrooms— "Chief of Staff," the "Chief Observer," and specialists for topics such as the environment, astronomy, plants, and animals (Carpenter, 1938). These approaches very much resemble the cooperative grouping approaches advocated by science educators during the late twentieth century.

Classroom activities necessarily made use of the limited materials available in each of the schools. Given the lack of adequate space and materials, the in school experiences were focused on listening and then discussion after the broadcast. As the program grew from a seventh grade only program to encompass an additional six grades, the amount of broadcast time varied according to the needs of the students. In the intermediate elementary grades, the broadcasts were typically fifteen

minutes in length, with approximately thirty minutes reserved for science discussion and activities in support of the broadcast.

The process also allowed for the students to interact with an expert to facilitate their learning. Decades before the Internet made student-scientist partnerships practical, direct communication between the science broadcaster and the students was a part of the operation of the Rochester Public Schools radio science curriculum (Carpenter, 1938; Tinker, 1997). A lesson on the movement of flies tendered this result:

> I believe I have discovered the reason why the housefly is able to cling upside down to the ceiling. With the aid of a microscope, I have been able to see a little suction pad on each foot. I believe the fly clings to the ceiling with the aid of this pad (Carpenter, 1938, p 208).

Other students reported similar observations to the radio teacher, developing a dialog between the learner and the mentor.

Even integrated instruction found a home, as students completed poetry assignments for their English classes, using the content from the radio science lessons as a starting point:

> Science is a study of the birds, bugs, and bees,
> The germs that try to harm us,
> And those that try to please,
> How very large the earth is, how very small a hair,
> Of wiggly worms and dinosaurs,
> Of gravity and air,
> How chickens can come out of eggs,
> Of how our hearts can beat,
> And why the lights go off and on, and how a snail can eat,
> And main in his environment
> How very small he seems,
> How crude and rough his implements,
> How foolish all his dreams (Carpenter, 1938, p. 208).

More objective measures of the success of the program were also available. Though the initial justification—pragmatism—provided the initial impetus to structure the science lessons around radio broadcasts, the eventual support came from increases in student learning and implementing the district's science curriculum. Student scores provided the impetus to continue the radio-based science instruction indefinitely. Available data

suggested a consistent positive effect among those students who participated in the radio science experience.

Table 1. **Student achievement scores, radio science group versus control group***

Examination Results for	Radio Science Group			Junior-Senior High Group		
	Middle 60% Score	Number Tested	Median	Middle 60% Score	Number Tested	Median
June 1933 7B	51-37	612	45	47-31	498	40
Jan. 1934 7B	54-37	2138	45	48-33	406	40
Jan. 1934 7A	69-54	588	63	69-50	837	60
June 1934 7A	87-70	1569	80	84-64	1103	75
June 1935 8A	...	332	78	...	2205	74

*From Carpenter (1937), Science in the Rochester School of the Air (p. 79).

Table 1 shows the consistently higher scores among those students in the radio science group as compared with the students in the traditional junior-senior high school science classroom, as measured by student scores on district science assessments.

This higher than expected set of scores on the district science achievement tests led to a larger scale implementation of the science radio curriculum across the Rochester School District and a number of the surrounding districts. This expansion beyond initial grade 7 group was 1100 (which included schools both in the district and out of the district) in 1933 to over 22,000 by 1937—a tremendous increase in participation in only four years.

Final support for the radio-based instruction of science was based argued in terms of efficiency and quality. Stated Carpenter:

> Teaching science by radio has, in my opinion, some advantages over the traditional method for certain grade levels; namely, the lessons are developed with greater care than would be possible for an individual teacher who is meeting five classes daily, with a total of two hundred to three hundred fifty individual pupils....Second, if the classroom teacher is relieved from routine lesson preparation, lesson presentation, the writing and giving of tests, and is able, therefore, to devote greater attention to individual pupils in her class (Carpenter, 1937, p. 81).

These arguments appear now as very much informed by the Taylor model of scientific management and efficiency—with each individual contributing a specific service to the needs of the overall organization.

The instructional advantages of the expert—bringing the world into the classroom through the eyes of an expert were justifications for the use of technology common to motion pictures, the television, and most recently the Internet.

> Teaching by means of radio makes possible the utilization of the services of an expert in each field of study, not only an expert in subject matter but [also] a master teacher (Carpenter, 1938, p. 239).

Efforts such as those of Carpenter, despite the valuable results and logic supporting their efforts, lasted only a few more years. The arrival of television on the instructional scene doomed the instructional use of radio to not much more than a historical curiosity.

2.1.3 Post Script: The Recent Past

Saettler (1990) neatly summed up the current state of educational radio:

> By the 1980s, publication and research relating to instructional radio had virtually ceased; course offerings in radio instruction were considerably reduced; commercial radio networks had closed their radio education departments and discontinued their school broadcasts; and the once-vigorous leadership of the radio Section of the U.S. Office of Education and the NAEB had disappeared. It was evident that educational broadcasting was shifting its focus from radio to television. Whether intentional or not, radio instruction had become the stepchild of educational technology (p. 218).

A more contemporary observation was made by Davis (1952), who in some ways understood the end of radio as a practicable part of the science curriculum: "The future of science on radio...is largely dependent upon what time on the available channel is left from the increasingly strident entertainment and advertising" (p. 81). With the ascendancy of television as America's primary entertainment medium, the perceived value of radio was displaced largely by the softly glowing cathode ray tube of the television.

3. LINKS TO SCIENTIFIC LITERACY

The links to scientific literacy demonstrated by the use of instructional radio were numerous. The Wisconsin School of the Air program <u>Afield with Ranger Mac</u> provided one example of using radio to fortify the instructional

content of seventh and eighth grade science lessons. The curious aspect of this particular program was related to the explicit Nature Study approach taken by the program, which would have been consistent with prevailing notions of scientific literacy during the 1900s, rather than the 1930s. Though the science content was more advanced than was typical for typical Nature Study curriculum, the message describe by the Nature Study approach was sadly of another era, yet communicated by the most up-to-date technology available.

As related to the findings of the National Society for the Study of Education's (1932) Thirty-First Yearbook, Part I: A Program for Teaching Science, the strong Nature Study component present in the Ranger Mac lessons is somewhat surprising, given the criticisms of Nature Study in the NSSE document. Given the short period of time between the issuance of the Thirty-First Yearbook and the Ranger Mac series, it seems reasonable to recognize this as another example of the slow rate of curricular change.

The vignette offered by Weibe (1945) offered further insights to the issue of scientific literacy. The suggested use of radio was to help create richer content knowledge for the students as well as to develop a sense of the business and agricultural issues connected to comprehension of the content. This notion has been consistent with most conceptions of scientific literacy, particularly at the secondary level (Commission on the Reorganization of Secondary Education, 1918; 1920; NSSE, 1932).

The trends and patterns emerging from the use of radio in the science classroom tend to represent the most conservative elements of what was considered exemplary science teaching during the 1920-1950 time frame. The focus on increasing the quality of information, while consistent with some elements of the science education community during that time frame, was slow to respond to more progressive, activity-driven experiences that were beginning to become more typical of the public school science experience.

The greatest concern with the use of radio as a tool for science instruction was the focus on the presentation of information more so than the interaction with materials—the classic "hands on—minds on" approach to science learning. Though some connections with progressive education were also apparent—connecting instruction with life experiences—the students were essentially passive recipients of knowledge rather than active participants.

4. TECHNOLOGY TRENDS

The narrative of this chapter is consistent with the pattern of technology infusion in science education reported by King (1999a; 1999b). The pattern of hardware-instruction-software is readily observable in the infusion of radio into classroom instruction. The work of Frost (1937), in particular, in his history of radio instruction in the United States focuses almost exclusively upon the presence of hardware in educational institutions, noting even the make and model of transmitters present.

The second and third steps in this evolution are apparent in works published later by Carpenter (1937, 1938, 1939) and the Wisconsin Research Project in School Broadcasting (1942). These two sets of work outlined the development of instructional practices in the science classroom with the use of the radio. Developing the pedagogy associated with the effective use of radio as an instructional tool was essential before its wider application in the classroom could take place.

Finally, Neal (1945, 1947) addressed the dissemination of appropriate software, clearly delineating the need for the identification of appropriate programming to suit the needs of science teaching. The challenge, of course, was that while Neal was making his remarks to the science education community, radio was becoming less of a concern to the nation both instructionally and as an entertainment medium. It remained at this point for television to take over and provide the next instructional technology of choice to support the aims of science education.

5. SUMMARY

This chapter examined the use of the radio in the science classroom from the 1920s through the 1940s. The two patterns of implementation were found to be common in science education. The approach used in Wisconsin exemplified a state level approach, in which instruction was developed and broadcast to serve the needs of the entire state. The school district of Rochester, New York developed a similar approach, but on a level that served the needs of a single district, and on occasion, the school surrounding the city of Rochester.

In both cases examined, significant improvements in student learning were achieved in classrooms that made use of the radio-based science lessons. By the end of the 1940s, however, science instruction using a

broadcasting approach had move from the radio studio to the television studio. The next chapter will examine the role of television in the science classroom.

Chapter 5

Instructional Television

Let's Explore Science

> In an era known as the age of science, it is appropriate that science itself should have developed television, a medium perfectly suited to the promulgation of scientific knowledge...Television, of all available media, is the ideal one for satisfying widespread public demand for science data (Poole, 1950, p. 1).

Poole's ambitious objective was the production of science-related television programs. In the early days of television, his view was one of many competing models for the most effective use of television broadcasting in the science classroom. The uses of television in the science classroom were examined in this chapter. The various approaches used to infuse television programming into the classroom were examined, along with a discussion of how the methods employed fit into the schemes of scientific literacy en vogue at the time.

1. BACKGROUND: TELEVISION AND THE PUBLIC

The telegraph's first public message was Morse's inspirational statement, "What hath God wrought?" The telephone commenced with Bell's urgent request, "Mr. Watson. Come here. I want you." Television commenced on a substantially different level of human expression: an image of Felix the Cat.

The invention of the television stems from investigations dating as far back as the 1870s, with many individuals providing discoveries and

inventions which would then be employed by subsequent inventors (Roman, 1996). Experimental stations began broadcasts during the decade before the Second World War; the war effort and the depression, however, precluded any large scale broadcast efforts from getting underway.

With the end of hostilities, network television broadcasting began in earnest in the 1940s. The decade of the 1950s

> witnessed a surge in the popularity of television, while radio was treated like an overlooked cousin. Most of the popular radio programs and their stars moved to the "electronic canvas." (Roman, 1996, pp. 158-159).

Like the motion pictures of a generation previously, public adoption of televisions as a source of entertainment and information developed rapidly. Television audiences numbered in the millions by the early 1950s, left the motion pictures far behind in terms of viewership. Measuring the impact of television on motion pictures by film business profits, the blows suffered by films were quite cruel:

> In 1946, the American film business grossed $1,700,000,000, the peak box office year in the fifty-year history of the American film industry. Twelve years later, in 1958, box-office receipts fell below a billion dollars; by 1962, receipts had fallen to $900,000,000, slightly more than half the 1946 gross. (Mast, 1981, p. 260).

With television pulling in so many individuals for entertainment purposes, the challenge to encourage its educational use was somewhat problematic; more programs were oriented towards entertainment than towards educational applications. Added to this were the different instructional formats television-based instruction offered for educational uses over the years: live broadcasts, taped broadcasts, closed circuit and satellite program feeds provided programming for science classrooms. This fact impacted people's perception of instructional television with the wide variety of instructional approaches that were used to reach students (Cambre, 1991).

> With so many possible variations, it is no wonder that there are often some misunderstandings about what ITV [instructional television] really is. The confusion is exacerbated by the multitude of delivery systems available to disseminate the television picture. The most common and cost effective transmission of the ITV signal is by satellite to the PBS stations, or to local cable companies or ITFS (Instructional Television Fixed Services) systems.... Few today expect the signal to be used live in the classroom. On the contrary, videotape has become the medium of

> choice for using ITV programming. Tapes may be recorded from the satellite signal or from intermediate distribution signals, or they may be purchased directly from distributors. (p. 268)

The challenges associated with the various approaches to information delivery informed much of the following narrative.

1.1 Educational Advocates

The educational possibilities offered by television were recognized almost from the beginning. Research into the most effective uses of television in the classroom began in earnest in the early 1950s. Refining the pedagogy continues to the present.

In the domain of science teaching, Crum (1971) examined a number of the issues associated with the effective use of television in the science classroom. As the producer and television teacher for the program Community of Living Things, he identified a number of factors that led to more effective use of instructional television in the science classroom. As both the teacher and the producer of the program, he used insights gained from both perspectives to inform his suggestions for infusing ITV into teaching.

Crum's (1971) main educational thrust in developing his programs was to develop student interest and involvement. A prime example was his use of observation sessions.

> "Observation sessions" are incorporated into the program. In these sessions the student observes film sequences without narration. This allows each student to formulate his own ideas about what he observes. It also provides a variation of the discovery or investigative approach while, as intended, directly involving him. (p. 39)

Crum had the advantage of being both a producer and teacher involved with instructional television. This allowed him to construct television learning activities from knowledge derived from two sets of experiences. As the instructional theory supporting the use of television developed, a more defined set of characteristics supporting ITV were developed.

Hawkridge and Robinson (1982) provided an answer to the question "What is educational television?". They identified four characteristics of educational broadcasting:

1. its programmes are arranged in series to assist cumulative learning;
2. they are explicitly planned in consultation with external educational advisers;
3. they are commonly accompanied by other kinds of learning materials, such as textbooks and study guides; and
4. there is some attempt made to evaluate the use of the broadcasts by teachers and students. (p. 25)

These characteristics, in addition to the following definitions helped to identify and make explicit the use of television in science education.

> *Educational television* [italics added] has come to mean many things to many people, as there is something educational in almost all forms of television broadcasting. *Instructional television* [italics added] is more specific in its meaning in that it is confined to the organized teaching-learning situation and is part of the formal instructional program of an institution of learning. (Smith, 1961, pp. 15-16)

Television's home in the classroom, whether organized along the dimensions described by Hawkridge and Robinson or less formally in the above "educational" sense provided much fodder for experimentation and innovation during the last half of the twentieth century. It also provided another avenue for educators to promote the ideals of scientific literacy.

1.2 Classroom Applications of Television

Hopes were high for the effective classroom use of television. The images and sound of the motion picture were combined with the immediacy of the radio to produce a technology that could reach into each classroom to promote science learning.

Television, because of the flexibility its hardware offered, also provided challenges to the initial groups of educators who sought the most effective means of infusing TV into classroom practice. Several models for the classroom use of the television came to pass.

Anticipating a number of the challenges of the use of television in the science classroom, Schreiber (1952) considered the similarities between the motion picture and television as instructional tools. He suggested that the educational issues related to television's use in schools were related to two areas:

1. The live (non-film) television program is an instantaneous reproduction of some, perhaps distant, event; whereas the motion picture may be a reproduction of the same event that is then projected for study at some later time.

2. The second difference, educationally, is one of flexibility in use. The live television program comes on only once and must be used then or not at all. It cannot be previewed, it cannot be adequately prepared for, it cannot be interrupted for questions, and it may come on at a completely unopportune [sic] time. (pp. 626-627).

Shreiber (1952), previously quoted as an advocate of film as an appropriate tool in the science classroom, identified several challenges for the use of television as compared with motion pictures: the issue of using live broadcasts and the appropriateness of the event would likely drive the instructional decision to adjust the course schedule to accommodate a live broadcast. More likely, it would simply be taped!

Shreiber (1952) also argued a philosophical point as to whether the nature of the television broadcast as a "live" event was a significantly different experience from a recorded event as represented by a motion picture presentation in the classroom. This question remains to be answered, but with the convenience of taping available today, it is a question seldom ventured.

Elsewhere he argued financially against the expenditure of funds to create a network of education broadcasting stations. His primary objection at the time was that there was little educational evidence to support the development of this sort of infrastructure. Motion pictures, he argued, would accomplish the same ends with greater flexibility (Shreiber, 1952).

Contemporaries of Schreiber, Levenson and Stasheff (1952) argued as forcefully in favor of the infusion of television into the curriculum. One factor they suggested as a strength of broadcasting was its timeliness--technology "presents and interprets the event while it is still current and before it becomes history." (p. 5) The multicultural educators of the 1990s would laud the further advantages of educational broadcasting. Television offered an opportunity to examine issues in detail by

> provid[ing] the classroom with windows on the world, with magic carpets that transport pupils to different lands, to other sections of their

own land, and to new and different climates of opinion and culture. (Levenson and Stasheff, 1952, p. 9)

Researchers at Fordham University, on behalf of the United States Army and Navy, carried out early investigations into the efficacy of television-based instruction. A number of general findings were based on these studies that supported the use of instructional television,

1. That television instruction is an effective means of training large numbers of reservists in widely separated groups. All grades of personnel made statistically significant gains on test scores for each of the programs.
2. That reservists not only learned from the television instruction, but they remembered most of what they learned when re-tested four or six weeks later.
3. That television instruction continues to be highly acceptable to the reservists after eight weekly sessions...
4. The amount of gain on test items is related to the explicitness of the topics on which these items are based...
5. The type of instructional treatment given a topic influences the amount of learning. (Rock, Duva, and Murray, 1952, p. 48).

Similar findings were found in a study conducted for the Navy, with additional suggestions for improving teaching practice. In particular the impact of television's production values--close up images versus distance shots, narration versus dramatization, and ensuring that the images and the audio track complemented each other--were significant in terms of the perceived quality of the experience by the viewer, and also in terms of the quality of the information gained. (Rock, Duva, and Murray, 1954)

Several other findings emerged from the study. Though the experiment demonstrated the usefulness and functionality of instruction via television, several suggestions were made to improve the experience. First and foremost, the visual nature of television made it essential that more visual aids for instruction be incorporated into the learning experiences. In addition, the performance of the instructor in a television setting was found to be of concern. A suggestion that a screening board "select instructors who are free from peculiarities in speech or other annoying mannerisms" was offered with the desire to promote more effective instruction. (Rock, Duva, and Murray, 1954)

These initial investigations into the instructional use of television provided early empirical support for the use of television as a teaching tool. The suggestion was made in the Army Report that selected channels be reserved exclusively for military use to allow for the efficient use of resources and ease of access to trainees. Rather than saving channels for the military, this suggestion was implemented on behalf of educational broadcasting for the general public.

In the nearly fifty years since Shreiber, Levenson and Stasheff, and others offered their thoughts about the value and purpose of educational television, a number of approaches have influenced classroom practice.

Beisenherz (1973) carried out an extensive study as to the use of locally produced science programs in the Seattle area and found further evidence supporting the infusion of instructional television into the science curriculum. In particular, he found that the use of television programs in science instruction influenced teachers to ask students a higher proportion of convergent questions than did the teachers in a control group. As this was part of the curriculum's goal--to develop increased use of questions at the higher end of a (modified) Gallagher-Aschner question system--the application of television as a useful tool in science instruction was given empirical support. His findings indicated that television could serve as a powerful tool for developing thinking skills among science students.

Klopfer (1980), drawing on several decades of experience, offered some thoughtful insights into the use of television in science education.

> Among the alternative forms for science education, the use of television as a medium of science instruction has a history of about two decades. The medium has now outgrown its infancy, and sophisticated programs dealing with science topics and science-related social issues are being produced with increasing frequency. The advent of convenient, affordable videotape and videodisk playback systems promises to make a powerful instructional alternative readily available, since viewing of televised programs is no longer restricted to times when they can be broadcast. Using the new tape or disk equipment, any group or individual could watch a series of personally selected science programs in television at any agreeable time. Via either playback systems or direct broadcast, televised science programs offer a means for expanding scientific literacy of the entire citizenry, not only students in schools. (p. 4)

Klopfer's positive and engaging vision for the use of television in science education contrasted with Schreiber's more skeptical view. Interestingly, as the technology developed, nearly all of Schreiber's objections to the use of television were addressed.

Removed from the speculations of science educators, the classroom use of the technology framed the investigation contained in this study. Different instructional approaches with different infrastructures competed for space within the available educational bandwidth. The motion picture, with a standard means of projection and a reliable set of software, found application quite rapidly in the science classroom. Unlike the motion picture, no approach to educational television has become the standard practice within the science classroom. Perhaps because there was no single dominant paradigm, educational television still remains a "sleeping giant" with untapped potential to influence teaching practice. While the basic tools are the same--transmitter, monitor, program and audience--the various arrangements using these components provided a range of possible classroom applications.

Standard commercial broadcasts, beginning on a widespread basis in the 1940s, provided a viable starting point.

1.2.1 Commercial Television Broadcasts

The original commercial broadcast networks were extensions of the existing radio networks. By the mid 1940s, a number of programs which could be considered "educational" were in place. As the networks defined "educational" differently, some questions arose with respect to the program's instructional merit.

The ABC network defined their educational mission in this manner:

> We feel that television is educational when it presents 'the dance' as much as when it is offering a forum discussion or showing the United Nations... We feel that news programs are educational. (Siepmann, 1952, p. 38)

CBS was also vague in describing the educational objectives of their programming, which they defined to include "the broad areas of programmes contributing to the cultural advance of the whole community." (Siepmann, 1952, p. 39) NBC offered the opinion that their educational aims were "to serve by television, and not to replace the home, the school, the church, the university." (Siepmann, 1952, p. 42) The Dumont Television network did

not articulate their educational philosophy for Siepmann's study, but among the programs they identified as educational was the "Johns Hopkins Science Review." This award-winning program was the first program on commercial television devoted explicitly to the investigation of scientific matters. The program's creator, Lynn Poole, offered two reasons for producing the program.

> First, a large segment of the population is interested in the topic as evidenced by the numerous magazine and newspaper articles that appear on aspects of modern science. Second, if science education is to continue in a democracy, its high costs have to be met by general public support of research. (Cumming, 1954, p. 13)

These reasons connected directly to the idea of developing scientific literacy.

The commercial networks, despite their overwhelming presence in the television broadcast arena, offered little in terms of programming explicitly related to science education. The occasional news broadcast or, in particular, space launch during the 1960s was the most common use of network television in science teaching. The use of the programming relied exclusively on the desires and interests of the classroom teacher, as resource materials were not typically produced in support of educational use of commercial broadcasts.

This trend of limited science-infused broadcasting held throughout the 1990s, with few exceptions. Short-lived programs such as <u>Walter Cronkite's Universe</u> found homes (briefly) on commercial television, but their tenure was rarely long-lived. In an interview with the producer of <u>Walter Cronkite's Universe</u>, the role of viewership explained the basis for most commercial broadcasting decisions was described by Lewenstein (1987):

> CBS producer Johnathan Ward explained that <u>Universe</u> failed because "it wasn't successful enough at building an 'evening.' We attracted people who did not normally watch TV. They would watch us at 8:00, then switch over to PBS to watch the second half of <u>NOVA</u>. They didn't stay with CBS, which is the name of the game in commercial broadcasting. (p. 33)

With the level of viewership providing an essential element for the commercial broadcast of science related television programming, the limited number of any educational programs--let alone science-related television programs--on network television has virtually excluded network-derived programming from having an influence on science teaching.

The viewership issue was even more critical than the tendency for viewers of science programs to change stations during their evening's viewing. Ward, drawing from the work of Jon Miller, further pointed out that the typical audience for science television programming was approximately 10 million (in 1984), and that these were in fact "the same viewers, hunting out science wherever it appears." (Lewenstein, 1987, p. 33) The audience appeared to be an extremely loyal one, but too small for network broadcasting.

Some efforts to rectify this situation came about during the late 1980s. A gathering of scientists and broadcasters, sponsored by the Scientist's Institute for Public Information gathered for a "Retreat on Science and Television." The key issues derived from this event were that scientists and broadcasters would likely profit from a greater intimacy and that the challenge of news broadcasting was to present scientific information in understandable ways in less than two minutes. Series of episodes related to scientific endeavor were apparently not among the issues discussed. A positive outcome emerging from the conference was the further development of a video archive that would allow better graphics to be used in television news programs to communicate scientific information to the viewers (Jerome, 1988).

As with the viewers described as "switching to public television" at the end of an interaction with commercial television, it is appropriate to do the same here, and examine the use of television in educational and public television.

1.2.2 Educational and Public Television

By the early 1950s, the desire for educational use of television was given public hearing.

> A total of 137 witnesses, most of them distinguished representatives of America's educational establishment, had formally testified at two hearings concerning the potential of TV in America as an instrument of enlightenment, training, and civilization. One or two dissents were heard, mostly from commercial broadcasters like the Columbia Broadcasting System. But, in main, the testimony was offered *en bloc* that TV had potentials to revolutionize education....(Gordon, 1971, p. 17)

As a consequence of this testimony, the Federal Communications Commission reserved in April 1952 162 Ultra High Frequency and 80 Very High Frequency channels for educational use.

In the ensuing years, a variety of instructional approaches have made use of these reserved frequencies. In the various approaches toward using television in the classroom, several aims were evident throughout the different efforts made to infuse television into instruction.

First and foremost was the belief that "television can improve the quality of instruction." (National Association of Educational Broadcasters, 1959, p. 122) Another issue, sharing sentiments similar to that of Thomas Edison, was that instructional television would serve to make education more efficient, in terms of both costs and the use of instructional facilities (NAEB, 1959).

The first educational television station broadcasting in the United States was WOI-TV in Ames, Iowa, licensed to Iowa State College (now Iowa State University). The fact that this was the only television broadcasting station in central Iowa from 1950 until 1954, as well as it mission as an agent of progressive agriculture, had a significant effect on the type of broadcasting offered by WOI, as compared to other educational stations (Caristi, 1997). The challenge experienced by WOI revolved around its position as a broadcast network affiliate with a strong educational mission. The profit/non profit and commercial/educational tensions were quite taxing for the organization. The conflicts inherent in this situation continued until 1994, when the Iowa State Board of Regents sold the station.

WOI-TV's first foray into science education, excluding programming offered by the farm extension services, was the program <u>TV Schooltime.</u> Offered "30 minutes, 5 times a week during the school year [and] designed for in-school viewing by elementary and secondary schools" (Cumming, 1954, p. 50) it featured, from time to time, science related program content. Science episodes were titled "Let's Explore Science" and the content ranged from life science investigations (a teacher and her students set up an aquarium) to simple topics in physical science (an investigation into the states of matter and its properties). In a program dealing solely with science content, WOI broadcast the series <u>Chemistry 101</u> during the fall quarter of 1955. Topics covered during this experiment into instructional television were those typically associated with a freshman course in college chemistry (Iowa State University, 1998).

1.2.2.1 Program Profile: TV Schooltime

Broadcast from 1952 though the mid 1970s, <u>TV Schooltime</u> was a long running educational program produced and broadcast by WOI-TV. Aired

each Thursday morning at 10:00 AM, the Let's Explore Science portion of the TV Schooltime series provided instruction in a variety of science topics for elementary students. In an informational report produced profiling the educational uses of television through WOI-TV, Davis (1953) offered several reasons why TV Schooltime's science programming was important. The ability to bring the specialist into small, rural classrooms was the key advantage of televised instruction, as well as bringing the "now" into the classroom--in the sense of the spontaneous events taking place outside and otherwise unreachable to the classroom. Bringing the classroom into the home life of the students was another advantage offered by televised instruction. Television, as a means of continued staff development, was another implicit purpose of its instructional application (Davis, 1953).

To achieve the purposes Davis described, Let's Explore Science was developed in this manner:

> Elementary school children are interested in the world close at hand, and in the universe beyond. Often, however, the elementary school teacher feels that the lack of equipment and technical training make planning the science program difficult. To help the teachers of Iowa meet this problem, Let's Explore Science is presented...It is hoped that, with the textbooks and selected references, these supplementary programs will help the teacher to plan an active science program which will capitalize on the scientific curiosity of youth. (Iowa Joint Committee on Educational Television, 1953, p. 45)

Supporting the teacher in his or her use of the program was a comprehensive teacher's guide. Each of the lessons was identified first with the broadcast date, and then with specific information to support the use of the program in science teaching. The guides for each lesson were divided into three parts: Part I covered what to do before the lesson--commonly hands-on activities related to the content of the program, a reading from the teacher, or research on the topic through some suggested literature.

Part II was the broadcast of the program itself, with the purpose of the broadcast lesson described in appropriate detail. Part III provided suggestions for continuing the activities developed both before and during the broadcast. The program was designed as a motivating tool for students to collect, organize, and create information. Additional activities were designed to help students connect the contents of the program with local industry, agriculture, and the needs of local communities.

Viewing sample episodes from the early years of the series demonstrated many of the instructional goals of the program and how they were to be implemented. In the inaugural episode from October 1952, a teacher and three of her students constructed an aquarium. Each step in the process was designed as a hands-on activity for students to duplicate in their own classrooms. Questions asked by the television teacher and the answers provided by the television students helped to develop deeper understandings of the needs for a small ecosystem (Iowa Joint Committee on Educational Television, 1952, October 2).

Broadcast later that same year, a follow-up episode with a different instructor focused on further exploring the needs of fish in the aquarium. A discussion of analogous situations and investigations with Cartesian divers, energy transfer, and a dissection helped to further develop student knowledge (Iowa Joint Committee on Educational Television, 1952, November 13).

Teachers and community members responded favorably to the programming. These comments were representative of those received by the station:

> I am a mother and I wish to express my gratitude to WOI-TV for the program TV Schooltime. Our children, like many other Iowa youngsters, attend a small consolidated school. We realize that the supplementary classroom help which these schools are getting could not possibly be obtained in any other way.
>
> We feel that TV is able to give us something we could not otherwise get.
>
> At present we are using the series in Guidance, Science, and Art. On the day preceding the science program, the teachers use the study guide for their class activity work. The students show a keen interest in each program and look forward to them with a good deal of anticipation.
>
> Several times we have performed experiments at school that were referred to in the broadcast. Eleven and twelve-year-olds clapped their hands from pure gratification to see that the TV class had the same experiences that we did. (Davis, 1955, p. 10)

During the 1950s, viewership increased year by year. Some limited data were available in surviving progress reports produced by station WOI-TV.

The increases in viewers recounted by the data in Table 2 quantitatively amplified the high regard the viewers shared immediately above.

Table 2. Progress Report on TV Schooltime*

	1955	1956
Total Number of Classrooms	278	312
Total Number of Students	7485	8329

*Davis, J. H. (1956). Progress Report on Iowa TV Schooltime. Ames, IA: WOI-TV, Iowa State College.

With the costs of television production rising sharply, the TV Schooltime series started, during the middle 1960s, to accept programming from external sources. Let's Explore Science ceased production and broadcasting during the 1960s. Multiple programs replaced it in the classroom. Each of its two successors reflected the changing ideas of scientific literacy, which were coming to the fore in the 1960s. In 1967, the final locally produced science series was begun, Iowa Television Science. It was developed with the process skill orientation evident. In its program profile, it stated:

> [Iowa Television Science]...has been developed upon the philosophy that science is more than just a collection of facts and a method. Each lesson constitutes a visual talking reference to help the children and the teacher understand the scientific method.
>
> Important course objectives will be to develop an inquiring mind and to develop the art of observation. Each broadcast will be open-ended to encourage teachers and pupils to search for answers in their own classroom situation. (Iowa Joint Committee on Educational Television, 1967, p. 3)

By the following year, no science programs were produced locally. Iowa Television Science ceased production after only one year. In its place, two new series supplied by a consortium of Midwestern educational broadcasters, Adventures in Science and Exploring the World of Science were broadcast, serving the needs of K-2 students and grade 3-4 students respectively (WOI-TV, 1968). The state's commitment to producing and disseminating science television broadcasting was also decreasing. Production of the teacher information manual, produced and distributed by the Iowa Joint Committee on Educational Television since the early 1950s, was discontinued. The task then fell upon WOI-TV to continue the process.

This background information on the two science programs was offered in the WOI-TV-published (1968) teacher guide:

> Exploring the World of Science is an exciting new science series which uses the inquiry approach to learning and allows students to observe, grasp concepts, and draw conclusions on their own.
>
> The lessons are designed to inspire learning, arouse curiosity, develop a deeper appreciation of nature, and encourage students to think in a scientific way.
>
> The open-end approach of teaching is used, encouraging students to investigate, inquire and experiment on their own, whether at school, at home, or in the out-of-doors, (p. 3)

Exploring the World of Science was very much influenced by the curriculum movements of the 1960s. The use of hands-on activities, complemented by the development of science process skill acquisition, was consistent with the best thinking in 1960s science education.

Adventures in Science, serving a younger audience, also reflected the perspectives present in the 1960s science curriculum movements. The focus on the process skills of science was in many ways a result of the broader conception of what should compose a science curriculum, with thinking skills recognized as an important complement to the content knowledge.

> This series is aimed at presenting basic science instruction in a meaningful and stimulating manner. Basically, the objectives of the course are to acquaint the students with the fundamental truths and specific subject matter of science. However, at the same time, it is to stimulate their interest and to motivate them to engage in a program of research and experimentation. And finally, to encourage "scientific thinking" based on logical and critical procedure. (Iowa Joint Committee on Educational Television, 1968, p. 5)

In February 1974, TV Schooltime ended its nearly 22-year run on WOI-TV. The establishment of a state network for educational television--which was running some of the same programs--had rendered the original broadcasting approach for TV Schooltime obsolete. The complete coverage offered by the Iowa Educational Broadcasting Network and the stresses of serving both educational and commercial needs as an affiliate of a commercial television network brought an end to this educational outreach to the people of Iowa.

1.2.2.2 Other Examples of Locally Produced Programming

Many of the early documents related to the instructional use of television had a certain "do it yourself quality about them. That is, in addition to

addressing many of the technical issues related to how a television camera works and issues related to how the television was to be infused into instruction, many of these volumes were replete with creating effective scripts and discussion of proper television production values. (Gordon, 1974; Poole, 1950; Cumming, 1954; Levenson and Stasheff, 1952).

One example of a locally produced television program came from Indianapolis in 1957. The local educational station had been used to "inform the general public about changes and developments in the public schools." (Barth, Payne, and Sprague, 1958, p. 202) Local interest called for an inquiry into the use of television in education. The objective was to test the viability of television as a means delivering content information to the students in several test sites.

> Consequently, in the spring of 1957, a series of television programs, designed for viewing by certain school classes was written and produced. As part of the series, four selected junior high school groups viewed specially prepared lessons each week for two months. The purpose of this plan was to attempt to add to the factual knowledge of the junior high pupil in the area of science and, experimentally, to determine if any difference in the knowledge of science facts could be observed between pupils who observed the science lessons and those who did not. If any difference could be observed, the worth of this technique of television teaching would be demonstrated. (Barth, Payne, and Sprague, 1958, p. 202)

Apparently the approach was worthwhile. Raw scores reported in the study showed that students in the television-viewing classroom averaged higher gains in content knowledge than did those in the non-television setting.

A similar approach was employed in the Des Moines, Iowa, public schools during the late 1950s and early 1960s. Each week, science lessons, among other topics, were broadcast for classroom viewing and instruction on school district station KDPS. One of the purposes behind the use of television was to

> enrich and supplement the child's experiences beyond what could be done efficiently and economically by the classroom teacher alone. (Montgomery, 1964, p. 110)

Sadly, following up on the experiences of station KDPS proved to be impossible by the 1990s. Station records had been lost and the current station director expressed surprise that the station had ever served a purpose other than as a training facility for high school students interested in broadcasting (Springer, 1998)*.

Reflecting in a more general way on her experiences using television as an aid in the teaching of science, Hadd (1971) offered some significant insights into the teaching process as supplemented by television.

> The TV set will never replace the classroom teacher, but as an elementary teacher I am not a specialist, and I welcome help from the television teacher. Teaching with the use of TV is a cooperative venture, or it may be looked on as team teaching...
>
> The TV teacher is a partner in my classroom. Every Tuesday afternoon he takes over part of my teaching assignment. He presents, explains, and demonstrates the major points in the lesson and stimulates student interest. My job is to clear up misunderstandings, make assignments, evaluate the students, and provide for group or individual activity. The success or failure of the TV teacher's efforts will depend heavily on my performance as a classroom teacher. He may do a superb job, but it will count for little if I fail in my half of the task. We must work as a team and support each other's efforts. (p. 11)

From the point of view of an elementary education director quoted by Hadd (1971), "In my opinion, the teacher who uses television to the best advantage uses her teacher's manual very carefully." (p. 11) The most effective uses of television in the science classroom came from effective planning and preparation, much of which could be derived from the teacher's manual.

As an advocate for instructional television, Hadd (1971) offered suggestions for individuals interested in duplicating her level of success. Regarding the physical operation of the television monitor, she advised warm up time and alternative seating arrangements for students. To improve the pedagogy, she made suggestions to novice television science teachers regarding using the television teacher as a motivator and idea builder for the students, and not as a substitute for the classroom teacher

* Springer, Bill. (1998, March 12). Personal contact. Springer served as the station director for KDPS during the 1990s.

1.2.3 Public Broadcasting System

Due to infrastructure needs, the cost, and the labor-intensive nature of the process, locally produced programming gradually evolved toward the development of the state, regional, and national broadcasting organizations. As costs rose, the need to cooperate grew (Cambre, 1991)*

Cambre (1991) and Middletown (1979) both characterized the growth and expansion of instructional television as something other than linear. Rather, it represented a process of "give and take" due to the desire for local control at one end and the economies of scale and improved production values at the other.

By the 1970s, a nation-wide system under the banner of the Public Broadcasting System (PBS) had emerged and subsumed some of the efforts of local and regional educational broadcasting agencies. Serving the classrooms and communities of America with a nationally organized system, PBS adopted an approach similar in appearance, though not practice, to the commercial networks.

Though many of the programs were still produced by local educational stations (in particular, flagship stations such as WGBH, KQED, and KCTS), the network approach allowed for a greater distribution of exemplary programs.

> The primary function of PBS was to help CPB [Corporation for Public Broadcasting] and the Ford Foundation develop suitable programs among the major production centers, which PBS would then distribute by interconnection. PBS was not to produce programs...(Saettler, 1990, p. 378)

Science-related programs distributed by PBS ranged from <u>NOVA</u> to <u>Bill Nye the Science Guy.</u> NOVA is one of the longest running series shown on PBS. Produced by WGBH in Boston, it sought to provide insights into the creative processes and mysteries of science. <u>Bill Nye the Science Guy,</u> sought to entertain and inform preadolescent through young adolescents. Created by and starring former engineer Bill Nye, <u>Bill Nye the Science Guy</u> offered insights for children into the role of science in society. Through

- Stated Cambre (1991): "One indicator of the imperative to cooperate is the continuously rising costs of production. Local productions in 1962 cost in the neighborhood of $165 per fifteen minute program. Today [1991] the estimate for high-quality ITV productions is approximately $3000 per minute." (p. 269)

engaging visuals*, fast editing, and parodies of music videos, Nye attempted to make the world of science engaging for children. NOVA, by contrast, was intended for a more mature audience and served more as an instrument of information and enlightenment.

Other programs broadcast through PBS informed and entertained students as well. Unlike the NOVA and Bill Nye programs, which did not produce teacher support materials in conjunction with their broadcasts, a number of PBS-sponsored programs did recognize a need for materials to support classroom practice. Others, profiled below, offered teacher support materials to supplement the broadcasts.

1.2.3.1 Program Profile: 3-2-1 Contact

By the 1980s, the increasing sophistication of the young viewer led to increasingly sophisticated programming. The series 3-2-1 Contact provided an engaging science education experience for children in the elementary grades. The goals of the program were stated as follows (Science, Technology and Human Values, 1980):

1. To help children experience the joy of scientific exploration and creativity and motivate them to pursue further scientific activities;
2. To help children become familiar with various styles of scientific thinking and to stimulate their learning skills so that they can learn to analyze important social issues related to science and technology; and
3. To help children--with special appeal to girls and minority children--to recognize science as a cooperative human endeavor open to their participation.(p. 27)

The goals of the program were clearly consistent with the 1980s view of scientific literacy. Science was to be considered an endeavor for all children--as noted in goal three and the promotion of thinking skills and evaluation skills represented an idea born with the progressives and institutionalized as part of the process skill-oriented curricula of the 1960s.

* Wilcox, Jim (1998, 31 March). Personal contact. Wilcox, a staff member in the Iowa State University Archives stated that many of the visual images used in Bill Nye the Science Guy episodes were repurposed from WOI-TV's TV Schooltime episodes. Apparently the images of students in 1950s dress with 1950s production values provides a nice contrast with the quick editing and dynamic animation to which contemporary students are accustomed.

The conclusion of each episode featured a mystery involving the Bloodhound Gang, a collection of genial neighborhood half-pint detectives who use their powers of observation and logic to solve baffling crimes like the case of the 264-pound burglar. Behind their capers is the idea that information-gathering techniques and creative thinking strategies are tools for scientists and detectives alike. (Thomson, 1990, p. 8)

The use of the Bloodhound Gang as an engaging means of developing the notion of science as a process of argument and evaluation resonated strongly with the view of scientific literacy present during the 1980s. The Bloodhound Gang, applying the tools of the scientists, was able to find answers to questions through problem solving techniques akin to that of the scientific method.

In addition to gathering interest with home viewing, the series was also designed to be used as part of a classroom science teaching experience. Consistent with the profile of educational broadcasting defined by Hawkridge and Robinson (1982), 3-2-1 Contact provided teacher materials, arranged the episodes in sequence to enhance learning, and was developed with input from a panel of specialists.

To assist teachers in the use of the program, teacher resource guides were published in conjunction with each broadcast. Several years after the initial broadcast of the program, Science and Children (Santoro, 1983) offered an in-depth profile of the series and the applications it had found in science education. The opportunities for participating in scientific endeavor, regardless of gender or ethnicity--the science for all Americans theme--continued to be an important part of the program's message.

A study undertaken by Johnson (1984) suggested that the use of 3-2-1: Contact as a tool for science teaching had significant positive effects on student learning. In particular, developing student interest in science curricula and in improving student knowledge of science concepts provided the prime areas for investigation.

> ...the children learned and retained many scientific facts, and, surprisingly, some of the knowledge gained was of the most abstract type. For example, a central topic during the series' "Flight Week" is Bernoulli's theorem about how flight can occur. Both before and after watching the programs, students were asked to explain how a wing can keep a plane up in the air. Prior to viewing, less than 25 percent of the

> student provided answers that demonstrated mastery of the concept. Afterward, 60 percent understood the theory. (p. 38)

Tomecek (1993) reported similar success with his use of 3-2-1: Contact. In his classes, he used the video materials as a means of setting up intellectual challenges and then examining them through the video episodes. Combined with a set of hands-on/minds-on classroom activities, the videos provided a natural link between the introduction of concepts and the investigation and analysis of the concepts.

1.2.3.2 Program Profile: Cosmos

Another series described as an "antidote... to scientific illiteracy" (Morrow, 1980, p. 25) was Cosmos. Morrow (1980) described the series in this way:

> Carl Sagan's labor of love is the enthralling epic everyone was hoping it would be. Heavy on astrophysics, but also embracing biology and culture, Cosmos takes viewers on a dual journey: through history, to the sources of scientific adventure, and through space, to its fabulous frontiers. Episodes include..."Traveler's Tales" which juxtaposes the Voyager saga with the nautical innovations of Enlightenment Holland, and "The Backbone of Night" in which Sagan's own quest to understand stars is charted from his Brooklyn boyhood to his recent experiences teaching children about the Milky Way. (p. 25)

Cosmos sought to entertain as well as enlighten. The historical thrust of the presentations placed the conduct of science into a context that was consistent with Science-Technology-Society (STS) perspectives on scientific literacy as the interaction of science and society.

1.2.3.3 Program Profile: Einstein's Universe

A highlight of late 1970s instructional television was the PBS special Einstein's Universe. Though the emphasis of scientific literacy by the 1970s offered a focus on process skills and problem solving skills, the essential role of content knowledge in the sciences could not be denied. An area of particular sophistication was (and still is) Einstein's theory of relativity. To assist teachers in the use of the program, Aviation/space magazine offered an overview of the program. It consisted not so much of a teacher's lesson guide, but rather an overview and clarification of the content of the program. The approach taken, in an effort to make the ideas comprehensible to the audience, was to feature a layman as the narrator. The actor Peter Ustinov

narrated the program. Identifying with the majority of the audience, he was frequently challenged to simplify difficult ideas and language. To aid in understanding, appropriate animation and narrative were used to offer clarification of the concepts developed in the narrative (Carlson and Walde, 1979). It is important to realize, too, that the information was not "dumbed down." Rather, it took what Carlson and Walde (1979) described as "Einstein's great achievement" (p. 29) and used his "vocabulary to think about the universe in ways that let us measure its properties." (p. 29)

Much like Cosmos, Einstein's Universe, emphasized the human element in scientific endeavors. This implicitly offered support of the idea that science was a pursuit that all people could engage in.

1.2.3.4 Program Profile: Search for Solutions.

Search for Solutions was a series of programs designed for students in secondary schools to help in the development of science process skills. The episodes in the Search for Solutions series included "Adaptation," "Evidence," "Patterns," and others. Each episode was designed to assist the student to appreciate the topic and its role in developing scientific understanding. Connections between concepts used in life and living (such as speech) were examined and used as a means of exploring how the patterns which make speech understandable were related to patterns in nature. The content of the episodes was engaging and thought provoking, with questions posed early in the episode revisited as more information was gathered. This was the intent of the series (Conover, 1980):

> The Search for Solutions program is about the process of science; the titles of the films are concepts and approaches to problem solving. The films illustrate how scientists...solve problems, which is the fun of science. (p. 1)

To support the use of the programs, a teacher guide was issued with each program aired. The contents of the teacher guide included instructional suggestions for using the programs, and hands on science activities to develop student interest in the activities. A feedback form was included to provide information to the producers as to what were the most valuable aspects of the issue.

Produced in the late 1970s and available from that point through the middle 1980s, the series was influenced by the need to address the use of science process skills as part of the programming. The project also addressed the more inclusive nature of the science education movements of the late

1980s, by including footage featuring scientists from under represented groups such as women, minorities, and the disabled.

Search for Solutions also adapted to the changing technologies of the time. Broadcast on television as well later produced for direct distribution via videotape, the Search for Solutions' teacher's guide offered a wide range of activities to support the use of the program in the classroom. The issues of the Search for Solutions: Teaching Notes (Conover, 1984a; 1984b) provided information and activities to teachers that encouraged both hands-on science activities and opportunities to apply the process skills (which provided the title of each episode) in an engaging and student-friendly manner were contained in each issue. Interviews with scientists provided a context for how professionals in the field created knowledge; the activities provided allowed opportunities for students to accomplish the same.

Engaging students though the programs extended to sponsoring contests in which students could engage in independent investigations. Using investigative skills identified and described in the programs Search for Solutions provided a significant part of the process. One judge mentioned, when reflecting on the entries he examined: "good use of problem solving principles found in the films." (Conover, 1985, p. 2)

1.2.3.5 Program Profile: Scientific American Frontiers

The program Scientific American Frontiers was a series of special programs appearing on PBS during the 1990s. Each week, a series of short episodes revolving around a particular topic provided a range of experiences for teachers to draw from to support their classroom practice. Teacher support materials included the right to use programs in perpetuity after taping and a teacher's guide issued in advance of each episode. Further support materials were available in the form of a toll free telephone service and an Internet web site (Scientific American Frontiers, 1998).

One of the interesting features regarding Scientific American Frontiers was its commitment to a cross-disciplinary look at topics examined in each episode. The February 1998 episode, for instance, included a segment on Benjamin Franklin's Glass Harmonica. Activities in the teacher's guide include not only science-related activities, but information to support learning in the fields of art, music, and technology. This view of learning and teaching was clearly consistent with the goals of both the National Science Education Standards and Benchmarks for Scientific Literacy. Both

documents advocated placing science learning and teaching in a context that would capitalize on the potential for interdisciplinary teaching.

Other programs related to science education include the 1993 series The Secret of Life. Teacher support materials were available free by request. An accompanying article in Science and Children served to emphasize a number of the issues in the series related to the 1990s conception of scientific literacy. Besides the content knowledge related to topics in biology, the infusion of issues related to biotechnology connects strongly to STS issues. The role of technology to effect changes, both positive and negative, in contemporary society represented and important facet of the 1990s conception of scientific literacy (Foley, 1993).

1.2.4 State Broadcasting Systems

State Broadcasting systems served the same purpose as the national Public Broadcasting System, though on a more regional level. No single model was adopted from state to state; variety was more common among their organizational approaches. The local systems were organized either by states, communities, or sometimes by single agencies. An early model of this approach was provided by Alabama (Saettler, 1990).

> The first state-wide educational television network was developed in Alabama in 1952. The purpose of the network was to raise the standard of instruction throughout the state, a goal most observers agreed was successfully achieved. Alabama's first instructional network utilized five television stations, offering classes on the elementary and secondary level to some 158,000 students. Taken all together, at least six hundred schools made use of instructional telecasts in Alabama. (p. 366)

Examples of programs supporting science education at the state level included such efforts as General Science, produced by the New Mexico state broadcasting system.

1.2.4.1 Program Profile: General Science

The use of a state broadcasting system to provide science instruction served a number of purposes. Having identified the problem of curriculum coordination among the teachers of Albuquerque, New Mexico, the use of television was proposed as a means of holding instruction together.

The solution to Albuquerque's (and New Mexico’s) difficulties with curriculum coordination was the development of the television series

General Science. Eddy (1971) described television science teacher George Fischbeck and the goals of the program:

> The main goal of Fischbeck's approach is to stir the mind of youth to like science. Thus, it is Fischbeck's aim to get the attention and to hold his interest. It is important, Fischbeck believes, to reach the young for science early in life. (p. 623)

The approach taken with the Albuquerque project was to supplement the classroom experience via television, rather than to "present the image of the master-teacher who presents brilliant TV program lessons." (Eddy, 1971, p. 623) To make the connections with the classroom teacher more effective, a series of teacher's guides were prepared as part of the television curriculum. The guides helped the teachers and students to focus on the relevant material presented through the television monitor. Remarked Fischbeck:

> "When the classroom teacher is on chemistry...we're on chemistry. But no teacher has to use us. We aren't usurping the teacher's right to teach--just helping out." (The Saturday Evening Post, 1962, p. 24)

During the program's first decade, it strengthened its focus on the process skills of science, reflecting in part the influence of the curriculum movements of the 1960s. In particular, the influence of Science: A Process Approach, developed through the auspices of the American Association for the Advancement of Science, were evident (Eddy, 1971).

The program also anticipated the inclusive nature of the scientific literacy issues of the 1990s. The need to involve children of color, rural youth, and other underrepresented populations was a concern during the 1960s as well. To exclude any students from an education in mathematics, science, and technology was unacceptable (American Association for the Advancement of Science, 1989). Through the television broadcasts, the lessons could reach

> people outside of large cities. Thus, the same program that is presented in Albuquerque on TV is also presented to Indian American students on the Navaho Reservation, Spanish American students in the mountain communities and other students in the small towns in the valleys of New Mexico. It has provided basic knowledge regardless of the student's background or his location. (Eddy, 1971, p. 627)

While Eddy described the population served in specific ethnic terms, the ideas he shared were reflected in the 1990s document, Science for all Americans, with the charge to open up the pursuit of science to underrepresented groups.

1.2.5 Closed Circuit Approaches

With the lower production costs available during the late 1950s and early 1960s, a number of school districts adopted a model of instructional television (IT) that relied on coaxial cables to carry the signals rather than standard broadcast frequencies. In the interest of improving instruction across the curriculum, the use of closed circuit television was identified as a means of improving content, instruction, and student knowledge.

For the purposes of this study, the closed circuit approach included, intra-school networks, school district networks, and also cable television. Cable TV has a much different connotation now than previously, related to its use as a commercial medium. This study examined cable TV as an extension of the hardware, rather than as a radical redevelopment of the programming presented.

Perhaps the best known use of a closed circuit approach to the curriculum was the ambitious effort of the Hagerstown, Maryland, school district. Beyond simply developing science instruction, the school district's entire curriculum was impacted by the use of a closed circuit television network.

The system devised was most comprehensive. The IT system reached some 6,000 students during the 1956-57 school year and achieved nearly 100 percent coverage of the district (some 18,000 students) by 1959-60 (Jamison, Klees, and Wells, 1978). By 1961, the broadcast schedule had assumed the dimensions defined in Table 3. What may be inferred from the table is consistent with the comments offered by David (1963). Televised broadcasting of science brought about both more science instruction at the elementary grades, and served to standardize the quality of the instruction.

Table 3. Weekly Televised Instruction Time[a]

Grade	1/2	3	4	5	6	7/8	9/10	11
Science	20[b]	20	25	50	50	159	159	
	(1)[c]	(1)	(1)	(2)	(2)	(3)	(3)	
Optional Courses								
Physics Films								90
								(3)

Table from David, 1963[a]
Minutes per week[b]
Number of class periods per week[c]

Investigations into student learning were also conducted as the programming expanded. Findings suggested that television instruction had a positive impact on student achievement.

The district's interest in using instructional television served several purposes. In a report (David, 1963) describing the district's use of televised instruction, a number of statements supporting the use of television to enhance science teaching emerged:

> Before television, the elementary science program varied greatly. Teachers with training and interest in science instruction developed rich programs. Others neglected all but the barest essentials. In the upper grades, where more teachers with college training in science were available, the program was probably most appropriate for average and above average students. (p. 59)

Following up on these issues, the project shared reactions from elementary teachers surveyed as to their thoughts on teaching science with television. Ninety-two percent of the teachers surveyed (out of a 99 percent return rate) preferred science with television; 4 percent did not care either way; and 4 percent thought the class would be better without the use of television. Their narrative comments helped elaborate the data collected (David, 1963):

> The studio teacher is able to bring to the classroom audio-visual aids, resource people, and instructional materials which would be almost impossible without television.
>
> The children get to see many visiting people who are experts.
>
> More experiments are performed than we could ever do in the classroom.
>
> The studio teacher devotes her full time to planning and organizing lessons which are excellent. No individual classroom teacher could possibly prepare a lesson as the studio teacher does with all the other subjects he must teach. (p. 61)

Further thoughts from the perspective of the teachers using television as part of their teaching gave more evidence to support the value they attributed to the use of television in their classrooms.

> I think television is wonderful for science.

> I don't like science very much but can truthfully say I have learned a lot from the television lessons. Please continue this work.
>
> It has stimulated much interest and caused children to attack research work with a desire to learn...I hope I never have to teach in a school where there is no television. (David, 1963, p. 61)

Teacher support of the televised science instruction was clearly high. Likewise, student opinions tended to support the use of television in the science curriculum. Their comments echoed those of the teachers (David, 1963).

> I like the experiments we can do with our television teacher.
>
> We learn new experiments which we can show our friends and do at home.
>
> Our teacher on television has all kinds of things we can't get for our classroom. (p. 60)

Opinion often produces changes, but data assists in keeping them. One measure of the success of the television-based curriculum came from a group of sixth grade science scores on the Stanford Intermediate Science Test. The findings suggested that there were definite advantages to the televised science programming in terms of improving test scores. The results were summarized in Table 4.

Table 4. Average Growth in Science Achievement in Grade Six by Three Ability Levels*

Ability Level	Pupils Receiving Televised Lessons		Pupils in Conventional Classrooms	
111-140	201	Pupils	84	Pupils
	118	Average Growth	117	Average Growth
	15	Months' Average Growth	12	Months' Average Growth
90-110	527	Pupils	365	Pupils
	100	Average Growth	100	Average Growth
	14	Months' Average Growth	11	Months' Average Growth
57-89	155	Pupils	146	Pupils
	83	Average Growth	83	Average Growth
	13	Months' Average Growth	6	Months' Average Growth

*Adapted from David (1963), table IX

Some methodological questions concerning the use of standardized test scores in the study were identified by Cuban (1986). The failure to control for socioeconomic status made it difficult to evaluate properly the impact of this technology on the learning of all students.

By the 1980s, after having struggled with funding problems during the 1960s and 1970s, the use of television as part of the district's overall teaching strategies had changed and found the use of taped broadcasts was the rule (Cuban, 1986).

Other school districts and individual institutions adopted the same approach as Hagerstown. In the early 1960s, the Anaheim, California, school district made a similar attempt to use closed circuit television as a means of improving the quality of education of the district's students.

Another example of closed circuit applications of television included work in the early 1980s work by Menis (1982). He addressed the use of a closed circuit approach for simulating laboratory work in the science classroom. Conceived on a much smaller scale than the Hagerstown approach, Menis (1982) sought the same goals. Noting the rising costs of laboratory materials, he developed a closed-circuit television broadcast of laboratory experiences. In his study, he determined that, for the material covered, the outcomes for the experimental and control groups were essentially the same. While he shared his preference for the actual laboratory experience, he pointed out the economic advantages of applying the closed circuit television model to classroom practice.

1.2.5.1 Cable Television

Cable television used essentially the same technology as the closed circuit classrooms, but on a much larger scale. As the availability of cable television broadcasts became more common, the idea becomes "narrowcasting"--creating programs for the interests of a small audience--became prevalent. This allowed the cable channels to speak directly to a specific audience, rather than an enormous one--allowed for some science education programs to be produced, which did not necessarily depend on an audience numbering in the tens of millions to succeed.

In the middle 1980s, Mr. Wizard returned to the airwaves after nearly a fifteen-year hiatus. Broadcast on NBC from the 1950s to the middle 1960s, it originated from Chicago station WMAQ. The updated Mr. Wizard ran on the Nickelodeon cable network, a channel designed for children's

programming. The purpose of his show was described in an interview with Don Herbert, a.k.a. “Mr. Wizard.”

> For Herbert, becoming Mr. Wizard was just doing what came naturally. He wanted to be a performer and a writer and had always been interested in what he called “Factual stuff--like science.” When he sold his idea to Chicago television station WMAQ in 1951, it began as essentially a magic show. (The “wizard” implied magic, but the “Mr.” give it respectability.) “My idea of doing science turned everybody off, so we used magic tricks to get people interested. Then we did the science behind the magic, like the egg in the milk bottle.” (Cole, 1984, p. 38)

The format of the show was rather informal in both incarnations.

> The new Mr. Wizard’s World covers a dozen subjects in a half hour whereas the old Mr. Wizard covered just one. It has a segment on computers, and, of course, is in color. Otherwise it has changed little. The child sidekicks are still challenged to slice a banana leaving the peel intact..., or lift a car with one hand,...or crush a can using that “invisible giant,” air pressure. (Cole, 1984, p. 38)

The program fit into the more “educational” type of science television, as it was not designed to support a particular curriculum. Of course, the impact on student development of scientific literacy was still present. During the 1980s, when employed as a high school physics teacher, students informed the author of this study on numerous occasions that a demonstration he had performed was something already demonstrated to better effect by Mr. Wizard.

The Discovery Channel, a cable network devoted to informational programming, also offered a series of programs designed specifically for classroom use. In addition to the programming--offered during the school day, but also available for taping to use at the teacher's convenience--they offered a set of support materials to use in conjunction with the programs, thus falling into more of an instructional than educational vein. The lesson plans were written to provide activities that supported the most current standards in science education. Other teacher support materials included references to on-line resources, questions for discussion, and ancillary reading materials.

Despite the variety of resources offered, reviewing some of the questions supporting the instruction tended to be convergent questions, addressing specific content of the programs, rather than using the information as a springboard to a deeper level of problem solving. Surprisingly, even the

process skills-orientation consistently advocated since the 1960s was not present.

1.2.6 Practices in the late Twentieth Century: 1980s and Beyond

By the middle 1980s, with several decades of experience to draw from, the late twentieth century offered several approaches to the use of television in the classroom were offered. One solution reflected the ability of teachers to control classroom practice and make an informed instructional use of the technology. The other approach reflected a "top down" use of the technology and its role in the teaching and learning of science.

1.2.6.1 Convergence with the Motion Picture

> Few today expect the signal to be used live in the classroom. On the contrary, videotape has become the medium of choice for using ITV programming. Tapes may be recorded from the satellite signal or from intermediate distribution signals, or they may be purchased directly from distributors. (Cambre, 1991, p. 268)

The statement above, composed in the early 1990s, underscored the most significant shift with respect to how ITV was utilized in the classroom. As discussed in the previous chapter, by the early 1940s the use of the motion picture in the classroom was a standard practice. It had attained a position comparable to the chalkboard in terms of being an accepted instructional tool. The changes in technology, however, changed the technology of choice from the motion picture to the videotape. The flexibility of usage described in the previous chapter allowed the videotaped motion picture to attain a position of preeminence in classroom practice. Not only was it a simple matter to use teacher-created videotapes, but the ability to bring recorded television images into the classroom eliminated the constraints imposed by inconvenient broadcast times. This convenience of access through taping was also helpful in using satellite broadcast signals in individual classrooms.

1.2.6.2 Satellite Broadcasts

Satellite broadcasts to individual schools were conceptually rooted in the aviation broadcasts of the early 1960s. Briefly, that approach used the advantage brought about by the airplane's altitude to broadcast instructional programs to the schools waiting below (Smith, 1961).

> The Midwest Council on Airborne Television Instruction was formed because of concern of educators in the Midwest, as in the rest of the country, with the challenge facing American education today--the challenge to provide sufficient quantity of educational opportunity for a fast-growing school population, along with increased quality of instruction, and to provide both quantity and quality within feasible costs. (p. ix)

The airborne approach allowed broadcasting to cover an extensive area, with signals reaching parts of six Midwestern states.

With the development and proliferation of communications satellites, a direct satellite link to the receivers located in a school became a reality. General-purpose satellite programming such as Whittle's Channel One brought satellite-fed programming to numerous schools throughout the United States by the 1990s. On a smaller scale, individual schools took advantage of an instructional television satellite link by the early 1980s. Though not as common as direct cable televisions connections, some rural locations found them to be exactly the solution to their IT needs they had been seeking.

The satellite delivery approach served isolated communities such as Circleville, West Virginia. In an effort to augment instruction, the school district arranged for the purchase of a satellite dish antenna. For areas such as Circleville, surrounded by mountainous terrain, this provided the first opportunity to make use of educational television (Dickson, 1981). This link to the "outside world" made it possible for teachers to use existing educational curricula to supplement their classroom practices.

One source of instructional material for the sciences was NASA. The connection protocols and services offered by NASA were described in on-line documentation:

> NASA Television (NTV) is a resource designed to provide real-time coverage of Agency activities and missions as well as providing resource video to the news media, and educational programming to teachers, students and the general public. (Dunbar, 1998, On-line)

To assist teachers and students in the use of the programming offered by NASA, comprehensive lesson plans were available for classroom use. Due to the cost of postage, by the late 1990s the materials were made available for access through the Internet, as well as through regular U.S. Mail should the teacher elect to pay for the postage. Topics ranged from the history of

space exploration through medical applications, weather observations, mathematics, and Newton's laws of motion (NASA Central Operation of Resources for Educators, 1998).

2. LINK TO SCIENTIFIC LITERACY

The birth of television as a consuming part of American culture began in the late 1940s with the economic expansion coming about at the end of the Second World War. The scientific literacy issues of the day were defined by the National Society for the Study of Education's (1947) Forty-sixth Yearbook. No mention of television was made in that document. Technology was addressed in terms of the use of the motion picture and slide films.

It should be noted that early instructional approaches using television were similar to early approaches with the motion picture. In the Indianapolis experiment described by Barth, Payne and Sprague (1958), the focus of the television approach was on developing improved content knowledge. This was consistent with the goals of scientific literacy a generation earlier, but included the use of a new technology to make the process more efficient.

The evolution of the programs associated with TV Schooltime helped to define the conceptions of scientific literacy from the early 1950s through the 1970s. Early episodes, based on viewing both the episodes and the teacher support materials, tended to focus on scientific knowledge and applications to the community. Given the largely rural Iowa audience of TV Schooltime, it even seemed to contain some elements of the Nature Study conception of scientific literacy. By the 1960s the focus of the program reflected clearly the science curriculum movements of that time. The role of problem solving and science process skills came to be an important part of both the desired curriculum and the content of instructional television programs.

The experiences of George Fischbeck and his General Science program helped to promote the 1960s view of scientific literacy. The early focus primarily on science content gave way to the broader view of science as having both content and process skill components. The evolution of General Science during the 1960s reflected this change in how science was conceived in education.

The 3-2-1: Contact use of a problem solving component to engage student interest was consistent also with the further development of the

scientific literacy concept. Within a few years of the inaugural broadcast of 3-2-1: Contact the prevalent idea of scientific literacy expanded to include problem solving as a component of the purposes of science education.

A study of several science television programs available via broadcast television and cable during the 1990s led to some interesting perspectives on the role of science television programs and the goals of scientific literacy. The data gathered by Long and Steinke (1994) showed the contrasts that educational programming offered. One of the primary contemporary tenets of science education was that science is for all Americans, regardless of age, gender, or social class. In each of the shows profiled (Bill Nye the Science Guy, Beakman's World, Mr. Wizard's World, and Newton's Apple), activities were demonstrated for children to duplicate at home.

> There is evidence in the shows that science is intended for everyone, not just white males. In all shows, viewers are encouraged to try the at-home experiments, thus indicating that anyone can do science.
>
> People on the shows represent multiple ethnic groups and both genders. Furthermore, females and children of color play important roles in two programs, often explaining or presenting scientific information. (Long, and Steinke, 1994, p. 22)

Though the overarching goals of scientific literacy were addressed, there were other aspects to the programs in conflict with the inclusion goal. These aspects tended to be in conflict with the process of science and had a tendency to reinforce stereotypes about the practice of science and of scientists.

The contemporary idea of science as a process of explanation and argument was not commonly presented in any of the programs. Drawn from their viewing of two programs, Long and Steinke (1994) presented this evidence:

> Another way that Beakman's all-knowing image is perpetuated to viewers is through the way that Liza and Josie introduce him to viewers. In one typical episode, Josie calls Beakman "the merchant of mentality," "the kaiser [sic] of chemistry," "the one, the only, the Beakman."
>
> Like Beakman, Mr. Wizard constantly displays his expertise though his explanations of science. Mr. Wizard always knows the answer, and Mr. Wizard is always right. As with Beakman, Mr. Wizard's expertise seems limitless. (p. 25)

Seemingly in contrast with the idea that science is for everyone, there was also a tendency for science to be presented as elite, eccentric, and antisocial. This was unfortunate, as the use of lab coats, fright wigs, and odd behavior sent strong messages to viewers as to not only the nature of science, but also who was deemed able to engage in its practice.

In some instances, there was a tiered system present with respect to the role of females in the programs. An examination of the same series of programs undertaken for another study (Steinke and Long, 1995), found that only 35 percent of the scientists shown on the program were female; the entire number of females on the programs was 52 percent of the entire cast. Furthermore, of the remaining female characters, many were portrayed in subservient roles such as laboratory assistants and apprentices. Clearly, the days of truly appropriate science programming are yet to come. The children's science education programs profiled were helpful in developing process skill and content knowledge, but also perpetuated a number of sex role stereotypes and misrepresentations of scientists as socially inept human beings.

3. SUMMARY

The use of the television as an instructional tool may best be described in Fischbeck's words: television wasn't replacing the teacher--but rather just "helping out." Though television did not revolutionize the teaching of science as early advocates such as Poole (1950) had hoped, it did provide a useful tool for bringing the world to the classroom as had the motion picture in previous generations.

As with the use of the motion picture, literature surrounding the instructional use of television presented three distinct phases:

1. Development of interest and focus on the hardware.
2. Development of appropriate pedagogy, and
3. Dissemination of software as the use of technology enters a mature state.

Examples to support this view were evident throughout this study. Examples of the first phase included Poole's <u>Science Via Television,</u> <u>Planning for Schools with Television,</u> and <u>This is Educational Television.</u> <u>Planning for Schools with Television,</u> in particular, highlighted the technical

issues associated with the hardware and classroom arrangements needed to optimize television teaching.

The second phase of television infusion, development of the appropriate pedagogy, was exemplified by works such as Diamond's (1964) A Guide to Instructional Television, which detailed many of the important instructional issues related to the use of the television in the classroom. Many of the examples he used were designed to demonstrate the effective teaching of scientific principles via television. Many efforts during the 1950s and 1960s (see, for example, Rock, Duva, and Murray, 1952; Rock, Duva, and Murray, 1954; and Levenson, and Stasheff, 1952; Midwest Program on Airborne Television Instruction, 1961) helped to develop and disseminate effective pedagogy for television instruction.

The final phase in the evolution of the television as a tool for science teaching--the dissemination of software--was more problematic than with the motion picture. The availability of useful science television programming was through either a locally produced set of materials (see TV Schooltime, Fischbeck's General Science, or the Hagerstown application) or through programs which were more "educational" than "instructional" (NOVA, 3-2-1: Contact, or the Scientific American Frontiers series). Instructional applications were adapted on a case-by-case basis for science instruction by classroom teachers.

Though videotaping relieved the teacher from being held captive to the broadcast time slot, the limited availability of useful classroom materials has been the greatest deterrent to more liberal use of television in the classroom. Some children's educational programming, despite the attention given to scientific accuracy of content, tended to support unfortunate stereotypes.

A final area for reflection had to do with the challenge of balancing entertainment versus instruction, especially when applied to the commercial television and cable ventures that were not related to a particular curriculum. The advantages of showing a diverse group of young people engaging positively in science would be considered a virtue; the entertainment value of placing television scientists in lab coats and fright wigs sent a different message.

Chapter 6

The Computer

From Teaching Machine to Telecommunications

Pressey (1927) offered these thoughts on a teaching machine he developed in the mid-1920s:

> The important feature of the work here reported is the exemplification of the fact that machines can be built which meet, automatically, certain very important requirements of efficient teaching. This apparatus is further evidence that labor-saving devices should be a possibility in the near future. (p. 552)

Seventy-five years later, the Microsoft Corporation promoted the use of their computer software with the slogan, "Where do you want to go today?"

These statements exemplified the development of the teaching and learning technology available first as a rather static teaching machine and decades later with the computer as a tool of self-expression and empowerment. The computer, in particular, was a technology with high interest in science education. Its implied promises of more efficient and more effective teaching and learning have placed on it a burden similar to those promised in earlier decades by the motion picture and education television. This chapter examined the place of the computer in classroom practice during the last third of the twentieth century. The uses of the computer and how it supported notions of scientific literacy supplied the overall structure for the narrative.

1. BACKGROUND

The invention of the computer can be traced back several centuries to technologies such as Pascal's adding machine and Leibnitz's calculating machine. These "analytic engines," mechanical in nature, operated conceptually much like the computers of the twentieth century. Rather than storing information electronically, data was stored, in the case of Pascal's machine, in a set of rotating, interconnected wheels (Bernstein, 1964). In a similar fashion, Babbage's analytic engines of the early 1800s accurately used the mechanical storage of information to accomplish all four arithmetic functions (Bernstein, 1964).

Though mechanical in arrangement, the conceptual organization of these machines was analogous to the computer, with a mechanism for entering information, for storing it, for processing information, and reporting results. Advances in technology allowed for more efficient means of relating these components; electronics proved faster and more reliable than mechanical gears and springs. The explosion in the growth and use of the computer during the last two decades of the twentieth century provided many insights into the power and flexibility of the concepts previously developed by Babbage, Pascal, and Leibnitz.

Unlike television and motion pictures, the pioneers who first brought the computer into the classroom had to have a greater degree of technical knowledge than the first users of the previously examined technologies. Early computers required a bit more devotion and preparation to use than did a television, which simply required plugging the device into a wall and selecting the desired channel.

The idea of the computer as a classroom tool was delayed several decades compared with the television and motion picture awaiting the development of suitable technology that reduced the computer from devices measured in the range of cubic meters to cubic centimeters. In addition, the development of appropriate software and pedagogy was also delayed--there were no equivalent technologies in the home; teaching with a computer was a unique experience.

A number of computers entered the classroom in the 1960s, with the majority entering the classroom during the 1980s and 1990s.

1.1 Educational Advocates

The earliest device that resembled the computer was the teaching machine. Wilderning (1961) offered a simple definition of a teaching machine:

> [The teaching machine is] a device which conveys information in unit form, demands a response, and then informs the student of the correctness of his response. (p. 579)

The computer eventually found itself pressed into similar duties. Though the computer is composed primarily of electronic components rather than mechanical ones, the applications for drill and practice types of learning were instructionally identical. The nature of the hardware provided the first limiting factors. The learning machines of both Pressey and Skinner were typically programmed in a very linear fashion, moving the learner from point A to point B in a fairly direct route. Some improvements allowed for more flexibility in terms of providing additional feedback in response to incorrect answers. The advent of the computer with the potential of following different learning paths present in the software allowed classroom use that could innovate rather than simply automate instruction.

Table 5. Categories of Learning with Instructional Technologies*

Instructional	Revelatory (Simulation)	Conjectural (Modeling)	Emancipatory (Labor-Saving)
• Drill and practice • Programmed Learning • Learning is led by computer	• Trying out a model • Varying external conditions • Discovering the nature of a model	• Making and testing a model of reality • Testing ideas and hypotheses • Drawing conclusions and discovering patterns from sets of data	• Computer as a labor-saving device, e.g., drawing graphs, calculations, capturing data
Computer in control			Student in control
Subject-centered Content-laden	←———	———→	Learner-centered Content-free

*Scaife and Wellington, 1993, p.26.

Moving beyond a device in which the primacy of the content was the focus of the tool, Scaife and Wellington (1993) considered the role of instructional technology as a means of empowering students. Their basic premise was that technology could liberate the student. The role

they conceived for technology in education is summarized in Table 5. The key effect of technology was as a means of emancipating the student and placing him or her in control of the information to be learned.

In essence, they saw technology as a tool. But as a tool, it allowed for the autonomy of the learner to increase as it was used in a more and more sophisticated manner. And the greater the autonomy of the learner, the more the use of the computer became consistent with the most effective approaches to teaching and learning science—in a hands-on/minds-on, inquiry-based approach. This information is represented in Table 5.

1.2 Classroom Uses of the Computer

As was observed with the previous technologies, groups of pioneer educators immediately seized upon the use of computer technology as a tool for the science classroom. Unlike the motion picture and educational television, the computer provided more numerous avenues for application in the classroom. According to the Office of Technology Assessment, by 1988 some 1.7 million computers were present in U.S. public schools. Other findings of note:

- Over 95 percent of all elementary and secondary schools now have at least one computer intended for instructional use, compared to 18 percent of schools in 1981.
- The current installed base provides an average of 1 computer for every 30 children enrolled in U.S. public schools....(p. 31)

Though the data were a decade old, the message was evident: the presence of the computer in the classroom was increasing.

Data from the 1990s showed that the availability of computers in schools continued to increase. The more important statistic of student use of computers [rather than the simple presence of computers in the classroom) showed dramatic increases in use from 1984 though 1993 (Table 6)].

Table 6. Student Use of Computers by Level of Instruction and Selected Characteristics*

Year	1984	1989	1993
Percentage of all students	27.3	42.7	59.0

*National Center for Educational Statistics, 1996, On-line.

Along with the presence and use of the computer, the software used to operate the computers was becoming more and more

available. According to Price (1989), out of "more than 7,000 software programs, nearly half support instruction in science and mathematics" (p. 30). In principle, any teacher interested in making use of the computer in his or her classroom had a choice of over 3,000 pieces of software. Training and the availability of hardware, however, kept the number of pioneer educators in science teaching relatively modest.

From the 1960s through the present day, science educators presented different means of using the computer as a tool to promote science learning. A 1982 article by Doyle and Lunetta described various uses of the computer in the science classroom. Through their experiences as an area education specialist (covering several counties in the southeast corner of Iowa) and as a university professor, they identified a number of exemplary uses of the computer in science teaching. The computer, they suggested, offered unparalleled opportunity to streamline classroom practice, especially with the ability to engage students in simulations and modeling. Recognizing the state of the practice, they offered insights into computer hardware, classroom practices with the computer, and a discussion of how some of the software available in the early 1980s might be employed. One of the most important issues of all: they made it clear that the purpose of the computer was to be a tool for problem solving and that its use would bring about misery for students and teachers alike if it were to be infused into instruction merely for the sake of using a computer.

Fazio and Berenty (1983) discussed this point as well. They recognized that for some time most classrooms would be fortunate to have a single computer; accordingly, they described their practices using a single computer in the classroom. Their focus for the effective use of the computer in the classroom was to make use of cooperative groups and a variety of activities occurring simultaneously in the classroom. The projects engaged students in computer modeling of geological formations; however, time on the computer was limited for each group, and other materials were available to support the interaction with the computer, such as databases, physical models, and textbooks. As the use of the computer was designed as an integral part of their earth science curriculum, it fit naturally into the series of activities. In addition, reported Fazio and Berenty (1983), the teachers composed the programs used for the course, adding to the goodness of fit between the use of the computer and the overall curricular objectives.

In the middle 1980s, Heikkinen and Dunkleberger (1985) reflected on the role of the computer in the science classroom. They recognized its potential

but reported on the challenges faced by teachers due to a perceived lack--despite the thousands produced by vendors--in the availability of appropriate software for science teaching. From their perspective, the potential of the computer would have been best realized as a tool to achieve mastery learning of science concepts though individualized instruction. What they offered to assist others to make use of the computer was an idea bank for the most appropriate use for the computer in the classroom. Suggestions for using the computer included achieving mastery levels of learning by individuals. What was lacking from their article was even one specific example of how it had been implemented in the manner they described.

Woerner, Rivers, and Vockell (1991) also saw the computer as a means of improving science instruction, with its applications existing on the same instructional continuum as Scaife and Wellington's (1993).

> If we let it, the computer can increase the effective academic learning time students spend learning the necessary and traditional content goals of the science curriculum. But more than that, the computer can indeed help us transform the emphasis in the present curriculum—learning facts, vocabulary, terms and sometimes misconceptions or thin conceptions—into an exciting and relevant curriculum that emphasizes concrete, real-world problem solving that has a technological and societal context. (pp. 9-10)

Drawing from the work of Tinker’s (1987) seminal article on the use of instructional technologies in the science classroom, the remaining discussion in this chapter is organized around his classification scheme. Rather than look at computers and software piece by piece, Tinker (1987) considered the role of computers in the classroom by the larger purpose they serve in learning science. In some respects, his characterization of the computer in the classroom was similar to that proposed by Scaife and Wellington (1993) in that the continuum reflected the increasing autonomy of the learner. Tinker (1987) saw this trend in terms of a transition from knowledge acquisition to knowledge generation. The first of Tinker's categories represented the use of the computer as an instrument of information acquisition. The others are data analysis, creativity, and communications.

1.3 Information Acquisition

Using the computer as a means of acquiring information is one of the most common applications of the computer in the science classroom. Among the activities Tinker (1987) found appropriate to this category were

the use of “telecommunications, videodiscs, [and] microcomputer-based labs” (1987, p. 468).

1.3.1 The Computer: An Object of Study

Perhaps because of the popular image of the computer as a "thinking machine,” the desire to learn about the structure of the computer was one of the first areas in which the computer found a place in the science classroom. Science texts such as <u>The Man Made World</u> (David, Piel, and Truxal, 1971) discussed not how the computer might be used so much as what the components of the machine were. The mechanics of entering information into the computer, the use of "iron powder rings" (p. 442) and the like focused the learner's attention on the hardware of the computer.

Perhaps taking the investigation of a computer to an extreme were a group of students from Bellingham, Washington, who constructed their own computer as an adjunct activity to their regular science coursework. Students learned applications of electronic theory and basic electronics while constructing their computer ("Computer Learning", 1978).

Less visceral in approach, Stavrides (1978) described the study of the computer as a separate entity in the Branch Brook Elementary School. To help develop familiarity with the computers that she was infusing into her classroom instruction, she offered this approach:

> Sessions before and after school are another aspect of our computer program. Any third though fifth grader can attend the after school sessions. A student receives weekly usage time on a rotating basis. The after school sessions continue throughout the school year. In the spring, second graders join the sessions. High school student computer volunteers help run the afterschool sessions. Our students learn how to turn the terminal on, how to log in and off, and how to get programs from the computer library. Children are encouraged to read about computers and watch for computers being used in the community. (p. 19)

Students in this setting, in an extension of their science classes, learned simple information related to the computer itself. Developing an awareness and familiarity with the computer itself provided the focus of the instruction. Developing student recognition of the role of the computer outside the classroom as a tool for business, industry, and science provided further encouragement in their use of the computer.

Computer programming provided another example of how the computer may be studied as an entity unto itself. Working one level deeper than simply examining the hardware associated with a computer, the experiences associated with programming a computer have had a number of advocates since the 1960s (see Watson and Watson, 1987). Project LOCAL, operating in the communities of Lexington, Natick, Needham, Wellesley and Westwood, Massachusetts, made efforts during the 1960s to train teachers and students in the study of computer programming to support mathematics and science instruction.

> The workshop was held because many schools starting to use a computer found that teachers who have only recently learned to program do not have sufficient experience to feel confident in the use of computers as instructional aids. (Slagel, 1969, p. 61)

The goal of the workshop was to help science teachers become more proficient computer users. To this end, they learned how to create programs that were designed to test student learning in a drill and practice format, as well as to design applications to test the relationship between variables. Applications for laboratory use and problem-solving investigations were also a part of the workshop (Slagel, 1969).

Elmer (1969) addressed similar goals. In his science classroom, the realities of 1960s science activities were addressed though the use of computer technology. More accurate data analysis was available through the use of class data sets. This process was facilitated by the use of a computer. Students and teachers learned to program the school's computer with the FORTRAN language as a means of processing data. Calculating the result from one activity led to individual student errors in the

> range of 14 to 20 percent, while the class-averaged values determined a value...with only 0.5 percent error--a valuable lesson showing why measurements have to be repeated many times. (Elmer, 1969, p. 69)

Through the computer, students were better able to appreciate the value of large data sets in the conduct of scientific inquiry. The primary drawback noted was that the process of developing the program by the students took in excess of five hours of time. However, on balance, Elmer (1969) believed using the computer as an occasional tool was worth the investment in time and effort.

Helen Presberg (1983), a science teacher at Hillel School in Rochester, New York, described the computer club she sponsored at her school and the experiences she had using club activities to enhance science learning. The

development of a few simple programming skills allowed students to create their own programs to apply to their science classes. For instance,

> once club members are taught how to generate random numbers, they can begin creating their own games....For our school's science fair, computer club members made up a quiz program for fairgoers to try. (Presberg, 1983, p.12)

An advantage of using programming as part of a science classroom experience was that the student's level of understanding needed to be sufficiently detailed to generate thoughtful science-related questions and then to organize them through the computer program scripting. The need to organize the information in a meaningful way and then to use the computer to help with the communication of this knowledge, whether through a student-created drill and practice or simulation experience, helped students to process their understanding of science knowledge. Presberg (1983) cited some examples of this approach:

> Another way to challenge club members is to have them create programs that are related to the science units they are studying in their science classes. Using the computer, students can plot the number of times a pendulum swings in a minute in relation to the length of the string to which it's attached. Or they can develop programs that determine densities, weights, and volumes, or that calculate the scales for making models of the Sun and the planets. (p. 12)

Presberg (1983) was able to use computer programming as a means of developing science thinking skills and as a means of complementing the components of her district's science curriculum. Another approach for using programming as a tool to develop science thinking was the use of LOGO (Parson, 1994).

> Logo is a computer programming language designed for use by learners, including children. One of the ideas guiding its creation was the principle "low floor, high ceiling." This means that it should be easy for the novice programmer to get started (the "low floor") writing programs and getting satisfaction doing so, but that the language should be powerful and extensive in a "sky is the limit" sort of way (the "high ceiling"). (On-line)

Campbell (1985) described taking advantage of the "low floor" aspect of LOGO for preschool children. Using the simple commands available with the LOGO language, students were able to direct a "turtle" across the computer screen. In terms of relating this to science teaching, the use of LOGO programming was related to the development of the space-time

relations process skill. Documentation from Massachusetts Institute of Technology also offered these reasons in support of its application in science teaching:

> Logo teaches problem solving, logical thinking, constructive methods and allows the user to interactively create and manipulate mathematical processes. (Parson, 1994, On-line)

By this reckoning, the use of LOGO was consistent with many of the curriculum reform movements of the 1960s. In essence, the real benefit of learning to work with LOGO was the ability to use programming as a vehicle for developing higher order thinking skills. Combined often with a set of Lego building blocks and a computer interface, students were able to create simple machines--applying their science content knowledge--that they were able to control by their skill as a LOGO programmer.

In the words of Papert (1980), one of the key developers of LOGO,

> I too see the computer presence as a potent influence on the human mind. I am very much aware of the holding power of an interactive computer and of how taking the computer as a model can influence the way we think about each other....For example, the critic is horrified by the thought of a child hypnotically held by a futuristic, computerized super-pinball machine. In the LOGO work, we have invented versions of such machines in which powerful ideas from physics or mathematics or linguistics are embedded in a way that permits the player to learn them in a natural fashion, analogous to the way a child speaks. (pp. 26-27)

In particular, his conception of "microworlds" helped to communicate the powerful ideas of science. In an example described in <u>Mindstorms: Children, Computers and Powerful Ideas,</u> Papert (1980) demonstrated how an entire "microworld," developed using Newton's Three Laws of Motion as fundamental principles, can be used to help students gain an understanding of the Laws of Motion. Manipulating LOGO turtles provided students an opportunity to examine and test these laws of motion. In the best Piagetian sense, students assimilated this information to construct their own understanding of the rules that govern motion.

1.3.2 Drill and Practice

The “drill and practice” application for the computer has been among the most traditional uses of the computer in a science learning setting. Its precedents, discussed previously, date to the learning machines of the early

twentieth century. While useful for teaching and learning discrete skills, it also had applications for higher order thinking and reasoning skills.

Windbigler (1978) addressed the use of a drill and practice approach to developing science knowledge. In his chemistry classroom, Windbigler (1978) designed a program that not only

> solve[s] every problem, but it [the computer] stores the answers, and prints an answer key for the teacher which can either be duplicated or posted for student reference. (If several problems are assigned per student, the computer prints a separate sheet for each, providing space for both computations and answers). (p. 25)

By using the power of the computer to adapt to the individual needs of the students in his chemistry classes, Windbigler (1978) accomplished several instructional goals:

- A large number of similar problems can be generated quickly, so that each student can be assigned a unique one to solve;
- The problem developed in the computer program can be stated in the teacher's own mode of speaking, making them seem familiar to students
- The programs are available for future use....(p. 24)

And finally, Windbigler (1978) found that creating the computer programs helped him to develop a better sense of where student difficulties in learning concepts arose. The process of developing his instruction in such an organized manner forced him to look more deeply at creating a "simple and unambiguous statement of the question or problem" (p. 24).

Other benefits arose from the perspective of the chemistry students. The drill and practice nature of the software allowed them to achieve a greater degree of mastery of the content knowledge. Windbigler (1978) noted that students frequently came in to the chemistry class during lunch periods and study halls in order to improve their scores (and hopefully their understanding) of chemical concepts.

Besides the specific content knowledge improvements, Stavrides (1978), who previously discussed the study of the computer as an object of study in and of itself, also commented on her use of the computer as a tool for drill and practice in the science classroom. In her view, the use of the computer served to develop higher level thinking skills as part of infusing the use of the computer throughout Branch Brook School's curriculum. She believed

that the need to organize information in such a way as to make the computer a useful tool for problem solving was one of the key advantages of its use in developing higher order thinking skills.

Programming remained a popular means of infusing the computer into the science curriculum through the 1980s. As has been seen with the examples cited previously, the instructors were most commonly the individuals who developed the program. This offered them the flexibility of developing the applications they needed in their science teaching. Cooper (1983) described some of her successes at having used the school's lone computer for her physics and chemistry classes. In an effort to encourage others to attempt these activities, she offered some samples of programs written in BASIC that she found useful. Her motivation was one that many teachers could identify with.

> School budget realities made it clear that buying instructional software...was not an option. The solution had to be one that cost the school nothing. (Cooper, 1983, p. 52)

Little of the article, save for a small section on how she made use of the computer drills she developed, addressed either the pedagogy or the broader goals relating the use of the technology to the issue of scientific literacy. Her primary motivation for using the computer was to automate her current instructional sets. The ability to automate current instructional strategies may provide the incentive for many teachers to infuse computer technology into their teaching practice.

To apply increasing interest in developing higher order thinking skills, a software program, the <u>Science Reasoning Series</u> (SRS), attempted to instruct students in the domain of the science process skills. It was first developed in the late 1980s. The goal of the team that developed these learning modules was to "make improvements in scientific reasoning for all students over...ten years old" (Bork, 1993, p. 335). While the efficacy of the software had yet to be demonstrated, the overall goal was consistent with goals of scientific literacy.

> The designers intend for the dialogs to be used in both formal settings,
>
> such as classrooms, and informal settings such as libraries....The series consisted of ten dialogs. The dialogs *Distance* and *Area* take on the process of the measurement process in science. In *Distance*, students use an on-screen ruler to measure the distance between two points. Variation

> among the responses of different students leads to a discussion of average and standard deviation. (Bork, Chioccariello, and Franklin, 1988, p. 79)

The software described above was rather unique among that available at the time. First of all, it was software available for purchase, which was a format that was not emphasized by the articles prevalent in The Science Teacher during the late 1980s. In addition, it focused more on the development of thinking and reasoning skills as an end in itself, rather than developing some degree of content knowledge as a vehicle for process skill development.

Among the projects making use of the computer as a learning tool was PLATO, developed at the University of Illinois in the 1970s. PLATO offered a means of delivering interactive instruction over long distances. With the mainframe computer located in Illinois, PLATO-connected terminals could be found at institutions (and homes) thousands of miles away, allowing instruction to take place far away from the physical location of the computer (Douglas, 1976; Modesitt, 1989). PLATO was connected to schools at all levels across the country. It was found, at the primary and secondary levels, to be helpful in teaching math and science skills (Tolman and Allred, 1991). Students engaged in PLATO-related tasks generally performed better than students in traditional classrooms used as controls.

Questions remained regarding whether the higher scores were due to the better organized instruction found in the PLATO software or if there was something intrinsically motivating for students using the computer (Douglas, 1976). Wise (1987), while not investigating those particular issues, found that students enrolled in a regular physical geography class and a PLATO-based physical geography class demonstrated significant differences in performance, with the PLATO-based students achieving higher grades. One area of particular interest related to successful students using the PLATO learning platform. There was a tendency for the most successful students to spend more time engaged in the learning materials. While Wise (1987) pointed out that this was not unique to computer-assisted instruction, it did suggest that the one-on-one nature of computer-based instruction might be helpful for students who excel in a more individualized learning situation.

Friedman (1993) described PLATO as a "victim of its own success" (On-line). A complicated path emerged from academic program to commercial product:

> PLATO was developed, as you probably recall, right here at UIUC, in the Computer-Based Education Research Laboratory (CERL). Eventually,

> agreements were reached with Control Data Corp (CDC) to develop and market PLATO, and most rights to the name were sold to CDC at that time...
>
> Eventually, CDC pulled back from their PLATO effort and sold the name and many of their rights to the system to The Roach Organization (TRO). Today, the name PLATO identified the TRO product in the CAI field. TRO's PLATO is essentially the same system that was developed at CERL. Just to make things more complicated, CDC stayed in the CAI business, and therefore had to change the names of their CAI product. (On-line)

TRO focused more on the use of computer-assisted instruction in the following way, serving students whose needs were not being well met in traditional classrooms:

> Whether for remedial programs that address dropout prevention and recovery, non-traditional programs for alternative, continuing, and adult education, or enrichment and vocational programs that prepare students for college or the school-to-work transition, PLATO courseware is an effective instructional resource that spans the breadth of secondary education. (TRO Learning, 1997, On-line)

Whether administered through a university as a part of instruction and public service or through a corporation motivated by profit, the findings indicated that PLATO, as with other computer-assisted learning approaches, was an effective tool for learning. The current economic viability of PLATO suggests that other applications for commercially provided learning software are a distinct possibility. If the software allows for a more explicit level of higher order thinking skills, it will perform a distinct service for students. This idea will be addressed in the following chapter in terms of what was anticipated by the use of the Education Utility.

1.3.3 Microcomputer-Based Laboratories

The microcomputer-based laboratory (MBL) concept offered the student and teacher a more engaging application of the computer than simple drill and practice applications. With the MBL, the computer served as a tool to gather, store, and (eventually) manipulate the data gathered via peripheral devices.

Whetting the interest of science educators for over a year were a series of advertisements in journals such as <u>The Science Teacher</u> and <u>Science and</u>

Children advertising and extolling the virtues of MBLs. The first detailed article (Graef, 1983) on microcomputer-based laboratories appeared in 1983. As with most early articles describing a computer application, it was very detailed in terms of describing the hardware, the costs of the hardware, and where materials could be purchased. Computer interfacing was described both conceptually and in rather explicit, nuts-and-bolts level detail. Some sample activities such as measuring pH, temperature, and investigations using photogates were described in terms of how the sensor, interface, and computer needed to be arranged. To assist interested teachers, a list of resources, both material and instructional, were included (Graef, 1983).

As an alternative for budget-conscious teachers, Seivers (1986) described how to use the game port from a number of microcomputers as an interface with temperature probes, light intensity meters and other simple data-gathering devices. This represented a means of using the computer as a data-gathering tool for the classroom. Seivers (1986; see also Horst and Dowden, 1986; Jesburg and Dowden, 1986; Westling and Bahe, 1986) also included samples of the computer programs he wrote so that the computer would translate the electrical signals into data for analysis. The challenge for the potential teacher, of course, was working with the computer hardware at a more fundamental level than the typical use of peripherals, as well as the need to make use of the BASIC computer language.

1986 brought several articles similar to the Seivers (1986) article to readers of The Science Teacher. Horst and Dowden (1986) and Westling and Bahe (1986; see also Kamin and Dowden, 1987) both described MBL activities which were engaging for students, helped to develop data analysis skills, and made use of common varieties of classroom microcomputers. The challenges, as with those described by Seivers (1986), were that some degree of mechanical and software expertise was required of teachers who wished to adopt these uses of the computer in the science classroom. Despite the glowing descriptions of the quality of the experience, there was little to encourage a novice in the use of computer technology to attempt this sort of investigation.

Raizen and Michaelsohn (1994) described the use of a motion sensor as a classroom tool. In an activity investigating motion and forces using inclined planes and carts, an elementary teacher secured a motion sensor from a high school colleague. The data collected through the peripheral device was plotted on the computer screen, with the parabolic path of the graph indicating that carts had accelerated as they moved down the inclined plane.

The vignette below brought the teaching episode to closure (Raizen and Michaelsohn, 1994):

> Ms. Popkin had used technology as a tool when her students needed to answer a question they could not answer using other means at their disposal. Changes that occurred over very short periods of time and were imperceptible to the unaided senses could be observed by means of a "microbased laboratory," or computer and sensor. Ms. Popkins students had found a problem that required them to call upon various skills and ways of thinking. They were fortunate to have a teacher who understands that there was no single route to understanding and who embraced the opportunity for students to solve a problem neither they nor she had encountered before. (p. 44)

The profile above illustrated the power of using the computer as a data analysis tool. The MBL provided a means of gathering information which was difficult to measure through casual observation and then processed the information in a way that would allow students to construct a more accurate understanding of the principles involved in force and motion. This dovetailed nicely with a statement from the National Science Education Standards on the role of technology in supporting scientific inquiry (National Research Council, 1996):

> The use of computers for the collection, summary, and display of evidence is part of this standard. Students should be able to access, gather, store, retrieve, and organize data, using hardware and software designed for these purposes. (p. 145)

Roth (1989) described uses for MBLs in the elementary classroom. Arguing in favor of the use of temperature probes, he made several points (Roth, 1989).

> When instruction focuses on higher-order skills such as interpreting data, making predictions based on previous results, testing hypotheses, and experimenting, the computer can quickly provide the data and graphs that become the basis for inquiry. The computer removes some of the tedium involved in data acquisition and plotting. Likewise, the computer reduces the amount of time taken up by certain hypothesis-testing activities. (p. 52)

To accomplish these goals of higher order thinking and increased efficiency in data analysis, Roth (1989) described several activities that lent themselves to investigation with temperature probes. The use of the temperature probe was especially appropriate. Though the same data could have been collected through the use of a thermometer, the ability of the

probe's attendant software allowed for the data to be more effectively manipulated. This helped students develop the understanding that the computer was a tool that could be used to both collect and analyze information--"that a computer serves more than one purpose" (Roth, 1989, p. 54).

1.3.4 Reference Tool

The computer as a reference tool was another of the uses of the computer as a source of information. Textual information, graphics, audio, video, and databases represented some of the ways the computer could be used as a reference tool for science teaching.

Kirschner (1983) described the use of the computer as a virtual assistant teacher--"my teacher aide, lab assistant and private secretary, all rolled into one" (p. 27). A strong advocate of hands-on science activities, the acquisition of several Commodore PET model microcomputers and a brief course in programming in BASIC allowed him to create a resource database for his classroom activities. He described a typical application of the computer in his classroom (Kirschner, 1983):

> When two groups of students asked me about the set up [for a laboratory investigation] I could help one group and send the other to the computer to see the experiment and the directions pictured on the screen. If another group had finished the experiment and wanted to verify their answers, the same computer program would check the answers and even offer tutorial help if the computations were incorrect. Groups that had finished the lab, but were still confused by the computations, could also use the tutorial help. It was like having a couple of extra teachers in the room. (p. 27)

In a similar fashion, Kirschner (1983) also devised a set of drill and practice experiences to assist his students in the attainment of specific science content.

Commercial vendors found that the production of informational software was well received by teachers. As it was similar in purpose to an encyclopedia or dictionary, the change in teacher behaviors required to use the software was minimal. It became a matter of sending a student to a computer to retrieve information rather than sending a student to the library. It could be infused into classroom practice with a minimum of changes in instructional strategies. Popular and engaging software products such as Microsoft <u>Encarta</u> conceptually resembled the standard bound set of

encyclopedias, but with the addition of audio and moving images and searching and hypertext-accessible information all contained within a single CD ROM. Software of this sort with a more specific science-related focus included ADAM (ADAM Software, 1995) and Views of the Solar System . These software products were designed as virtual textbooks of information, but with interactive aspects.

Views of the Solar System (Hamilton, 1996), scripted in Hypertext Markup Language (HTML), enabled students to follow an information-seeking path that helped them to seek information based on need and interest. In addition to text and graphics, the software also included a database of planetary information, video images, audio clips, and external links to web sites to access the most current information available. Since the program was scripted in the language of the Internet, it was an exceedingly simple matter for the program to be delivered directly to a location on the World Wide Web. With it, the most current information regarding space sciences, planetary studies, and related information held in the public domain by NASA were available.

ADAM, designed for a younger audience, was an engaging program designed to help students learn more about systems of the human body. Each layer of skin was removable, which assisted students in developing an understanding of the relationships among the various bodily systems as well as their location in the human body. Health concerns and concepts were interspersed with (occasionally humorous) audio and animation to make the use of ADAM an engaging tool for students.

In addition to a popular videotape series, the Magic School Bus was also available in CD-ROM format for students. Designed for students aged 6-10, the programs allowed students to gain content knowledge in a number of science areas. To make the process more engaging, games and puzzles were interspersed to involve the students in the learning tasks. In the software, The Magic School Bus Explores Inside the Earth (Microsoft Corporation, 1996), students were given introductory information on plate tectonics and then challenged to reassemble the pieces of a puzzle fashioned to resemble the Pangaean super-continent. The emphasis of The Magic School Bus series was on the development of science content knowledge. As a companion piece to the ADAM software, The Magic School Bus Explores the Human Body (Microsoft Corporation, 1995) offered a number of activities designed to help increase student knowledge of the human body, with an approach that offered more games as a means of learning content.

The Internet was lauded as a virtually unlimited source of information for teachers and students. One of its primary uses has been a source of a wide variety of information. Before the Internet became a medium of commerce, a key method of securing information was through file transfer protocol (FTP). Lundberg (1995) offered teachers an introduction to gathering information through the FTP process. The method he advocated was through the use of a text-based browser, which made the information more readily available to schools and teachers with slower modems. His reason for using the Internet was twofold:

> As a high school biology teacher, I wanted to get information on science. I also wanted to get computer programs that my student could use to help them in the classroom. (Lundberg, 1995, p. 34)

Lundberg (1995) made a strong case for the suitability of this process for teaching and learning. In terms of the broader goals of scientific literacy, the primary concern was that he presented FTP as a teacher tool; the process was simple enough that students could have made use of the technique to find the materials they required themselves. As the software advanced--particularly the graphic browser--and access to the Internet continued to increase, that concern disappeared. Students now have full, easy Internet access.

Berg (1995) suggested the use of computer bulletin boards (BBS) as a means of gathering information, in much the same manner as Lundberg (1995) advocated the FTP process. Again, the focus was primarily on the teachers' use of the materials acquired from the BBS. The student use of materials derived from the Internet became more common with the greater availability of the Internet in the classroom. Only then did the computer become a more emancipatory tool, freeing the user from some degree of repetition and drudgery; in addition the computer became more learner-centered.

1.4 Analytical Tools

The use of the computer as an analytical tool represented the second of the science class applications of the computer identified by Tinker (1987). This set of applications moved the computer-student experience further in the direction of increased student autonomy in that the student was engaged as an active participant in the activity. The use of the computer allowed for students to analyze data, rather than to simply collect it, or to use the technology as a simple source of content information. Among the experiences he listed in this category were the computer as a means of

analyzing "database/spreadsheet [applications and] graphing/statistical [tools]" (Tinker, 1987, p. 468).

As a tool to organize information, the computer had some natural advantages. It was able to manipulate large quantities of information. It could remove drudgery from some operations. In a set of class activities described by Kenneth Fuller (1996a), a teacher at Faye Ross Junior High School in Buena Park, California, related how he used computer software to develop classification skills among his students. Making use of a simple

> kind of artificial intelligence that involves teaching the computer to identify various animals in response to the students' yes-and-no answers....my objective for the students is that they teach the software how to make distinctions among a group of animals by means of a series of yes-and-no questions. (Fuller, 1996a, p. 22)

Through the use of this simple software, Fuller was able to help his students focus on the characteristics of animals as a means of helping them to master the classification skill. In this way, the computer and its attendant software became a tool for analysis rather than simply a reference material, with the software guiding the students' thinking and learning.

Nelson and Harkins (1971) described another perspective on the use of the computer as an analytical tool. Their early use of the computer in the science classroom applied the computer's ability to examine large quantities of information, process the data, and then to use the results to identify statistical outliers in a data set. In this way, the computer served as an aid to developing higher order thinking skills. Comparing single scores with group means served the instructors with an aid in discussing systematic and random errors.

1.4.1 Simulations

Simulations, along with drill and practice programs, provided some of the earliest applications of the computer within science education. In a simulation, the software allowed the user to engage in an activity that resembles a "real-life" event. Simulations were helpful in learning to detect patterns and in examining the effect of changing a variable on the overall outcome of the activity.

Showalter (1970) struggled in the early days of educational computing with two critical problems for teachers: the lack of software and the high cost of the hardware. To make effective use of computer simulations in his

classroom, Showalter (1970) addressed the lack of software by creating his own simulations. Ranging from one controllable variable to eight, he composed simulations ranging from a study of maze learning by rodents and paramecium populations in closed systems to the reaction rate of magnesium in hydrochloric acid to sliding friction.

Key among the observations that Showalter (1970) made with respect to the use of simulations was the role of the variables in the programs he developed. The flexibility of the variables seemed to be helpful in engaging student interest in the activity. This, combined with Showalter's (1970) view that not all student-controlled variables should have had an effect on the outcome (as a means of helping student investigators to learn to pursue fruitful lines of investigation), contributed to engaging students more deeply in the investigation. The simulations extended traditional hands-on investigations in the classroom but did not replace them. The simulations went beyond what was achievable in the classroom and encouraged the student to experience and hypothesize in areas for which classroom investigation ordinarily did not allow.

The middle 1970s brought another simulation to light for the science classroom (Moore and Moore, 1977a). Surprisingly, it was the first article on the use of computers published in <u>The Science Teacher</u> since 1970. As with a number of the previous articles describing the use of computer technology in the science curriculum, this article also profiled a piece of simulation software. The article was published not as a more common "how to" article, but rather as one of a series of articles on the interaction of science and society. Its purpose was directed at informing teachers of some potential consequences of continued resource depletion and to elaborate on how a computer model was able to help accomplish this task.

The following month, a second article (Moore and Moore, 1977b) on computers appeared, tying in nicely with the interest developed in the previous month's article. With the development of the microprocessor in the early 1970s, Moore and Moore (1977b) explained the nature of the new technology and some of its implications for science teaching. In this article, the terms RAM, ROM, bits, bytes and many terms familiar to the computer users of following decades made their first appearance in a journal sponsored by the National Science Teachers Association. This contributed to increasing the awareness level regarding computers in the science classroom, including applications software--such as simulations.

In the early 1980s, as more and more articles on software describing software were published and found their way to practicing teachers, Elron (1983) used the pages of Science and Children to report on the available science simulation software. By including a number of factors related to the optimum educational purposes for a simulation, he described a situation in which students were able to gain a sense of the relationship between variables. Related to this, students were able to understand how changes in a single factor would result in changes in the entire system--both intended and unintended.

A number of consistent problems appeared in the software he examined. Some of the technical limitations of the software forced the investigation to be restarted each time an adjustment was make in conditions, rather than adapting from the time the changes were introduced. Many of the software programs were more suitable for single individuals, rather than group interactions, which placed a hardship on classroom organizational practices. Some of the interactions were also a bit limiting, since "most simulations designed for elementary and middle school limit the range of issues" (Elron, 1983, p. 15). This presented difficulties when examining issues in a broader context, the implied advantage of a simulation.

Tocci (1981) found that simulations were becoming an important part of his biology classroom. As an instructor with a completely individualized learning program, he found the computer an excellent resource for both managing information and for student learning. In particular, the simulation was determined to be exceedingly helpful in developing a sense of how changes in systems work to restore equilibrium.

The classroom activities described by high school science teacher David Saiz (1994) combined elements of computer simulations with the addition of creating one's own applications. For his classroom, Saiz created a number of simple applications that allowed students to investigate the effect of changing variables on phenomena such as a pendulum, waves and frequency, and population changes among predators and prey. The idea of using the technology to help all students achieve was part of Saiz's purpose:

> I have occasionally found it difficult to teach the relationship between wave frequency and wavelength to lower ability students. The obvious solution was to write a computer simulation that could utilize the PC's graphics capability to plot several waves on the computer's screen in succession. Once a student can see (and hear) several sound waves of

> different frequencies in sequence, the relationship between the wavelength and frequency is suddenly much clearer. (Saiz, 1994, p. 30)

In addition to teacher-written software, commercially produced software also found a home in the physics classroom. Several of these were examined as a means of sampling teacher classroom practice as related to the computer.

1.4.1.1 Program Profile: Interactive Physics

Interactive Physics cleverly created a universe on the computer screen. The interface between the user and the computer was graphical in format. Rather than responding solely to a set of numbers describing an event, the user was able to manipulate images of inclined planes, springs, and objects of varying mass simply by drawing the object on the computer work space and then setting the system into motion. Its simplicity of operation and the ease with which it was introduced into the curriculum led to its receiving several awards by the software industry (Knowledge Revolution, 1997). Its popularity, quality, and ease of use led to its inclusion as a supplemental activity in textbooks by Hewitt (Conceptual Physics), Serway (Principles of Physics), Giancolli (Physics Principles with Applications) and others (Knowledge Revolution, 1997). The activities supported by the use of the Interactive Physics software was consistent with the scientific literacy goals outlined in Benchmarks for Science Literacy. Benchmark 8E, Information Processing, suggested that "students should all become comfortable using computers to manipulate information..." (AAAS, 1993, p. 200). More specifically, the benchmark for grades nine through twelve opined that students should know that

> computer modeling explores the logical consequences of a set of instruction and a set of data. The instructions and data input of a computer model try to represent the real world so the computer can show what would actually happen. In this way, computers assist people in making decisions by simulating the consequences of different possible solutions. (AAAS, 1993, p. 203)

Comparing the benchmark outlined above with descriptions from the product catalog displayed a number of similarities:

> Interactive Physics offers powerful tools for modern learning, [helping students to engage in] model building for active, constructive problem solving, [and allowing for] simulation controls [that] provide opportunities for students to repeat investigations over and over and

> construct an understanding of the affect of incremental changes in variables. (Knowledge Revolution, 1997, p. 11)

Besides the physics concepts, simulations enhanced other disciplines. Fuller (1996b) described the use of simulation software called Buffalo which students used to develop concepts in ecology. Experienced as both a science teacher and an advocate of technology, Fuller provided transcripts of classroom discussion to demonstrate the role of the computer in the classroom as a means of developing student's thinking skills. The software allowed students to set initial conditions regarding the formation of a herd of buffalo. Fuller challenged students to look at the problem in different ways; the computer served as a means of testing their newer and more refined understanding of the ecology of animal herds. The computer became a tool for the testing of hypotheses related to optimizing the size of a buffalo herd (Fuller, 1996b).

In a subsequent article, Fuller (1996c) described other software applications that were helpful in teaching quantitative thinking.

> While observing students play the game during their free time, I can see that they consider themselves to be business successes; many quickly achieve the season's goal of $2,500 suggested by the program. Yet, at this point, I have never observed *any* student doing *any* calculating. By trial and error, the players often develop an intuitive sense that works for the numbers and amounts but they never decide consciously that math is appropriate to the situation. (p. 16)

By setting higher goals for their earnings from their concession stands, the students began to identify the factors that impacted the price of the goods, the condition under which the goods were sold, and the price charged at the retail level.

Though the content of the activity resembled something from an economics class more than a science course, the critical principles of examining the reasons why a model worked, and most especially in this example, how to use quantitative data effectively were skills that were useful in any science investigation.

Kirschner (1983), previously profiled for his use of the computer as a virtual classroom assistant, also developed some software for classroom use to help students analyze and interpret their data. As with other classroom practices examined, the opportunity to gather an entire classroom set of data for analysis proved to be one of the most helpful aspects of the process.

Histograms of student data could be printed and examined immediately, connecting the data processing with the data collecting in rapid order.

Data analysis through the use of the computer was advocated by Zeisler (1985) as well. She used the computer as a means of checking data for accuracy and as a means of helping students to deduce patterns from the data they had collected (Zeisler, 1985).

> My students manipulate the apparatus fairly well and they gather good data, but they often make errors in calculation. Errors, even small ones, yield values that don't conform to the pattern that students should find. If there is no pattern, the young experimenters won't be able to form valid conclusions....(p. 36)

To this end, Zeisler (1985) used the computer as a means of helping students to identify answers to calculations that were inconsistent with the data the students had collected. By eliminating answers obtained in error, the students were able to use more valid data to help themselves deduce a reasonable relationship between the variables. To assist teachers with this use of the computer, Zeisler (1985) included the complete program written in BASIC that she used for her chemistry class.

1.4.1.2 Spreadsheet

Seivers (1985; see also Schlenker and Yoshida, 1991; Schwinge, 1985) described the spreadsheet, identified by Tinker (1987), as an analytical tool well suited for classroom use. Besides his use as a management tool for ordering materials and organizing laboratory equipment, students found it to be a helpful tool as well. Students were able to organize and solve for resultant vectors in a physics class and also to conduct a simulated chemistry titration through the use of a spreadsheet (Seivers, 1985). Other suggested applications included an examination of Ohm's law, of radioactive decay, and of a predator-prey simulation (Schwinge, 1985). This use departed from conventional simulation in that students were required to enter the formulae before the investigation could be run. This involved students at a deeper level in the development of their ability to use equations to describe scientific phenomena.

Pogge and Lunetta (1987) and Kellogg (1993) also argued on behalf of the spreadsheet as a science learning tool. By using the spreadsheet as a tool to analyze data, students were more able to focus on relationships and processes than on the accumulation of numbers. For more sophisticated investigations, spreadsheets allowed for statistical significance testing.

Pogge and Lunetta (1987) made use of not only a *t* test for high school students, but were able to examine data sets through an analysis of variance. The tedium of calculation was removed and the focus remained on the data and hypothesis-testing aspects of the scientific endeavor. Kellogg (1993) found that the spreadsheets set up as templates had an important role in the classroom as a means of confirming knowledge which had been previously developed through interaction with laboratory materials.

Also streamlining the process were computer applications described by Michael (1989). She described the use of the computer as a means of representing data graphically to engage in the graphical analysis of the information collected. In this way, she could assist students in deriving the mathematical relationship between variables. While this process could be done without the use of the computer, Michael (1989) suggested that it allowed for more time to be devoted to analysis of data rather than the mechanical creation of a graph.

1.4.1.3 Other Analytical Software

Spreadsheets were a piece of software available on virtually every computer sold after the middle 1980s. More specific types of analytical software helped students to better appreciate the role of the computer in the conduct of contemporary science. One such program was GIS--for Geographic Information Systems (Fazio and Keranen, 1995).

> GIS is a computer-assisted system for the acquisition, storage, analysis, and display of geographic data. It contains maps and associated information in digital form. The system profiles access to information as well as means of linking together geographic data. The ultimate purpose of GIS is to act as a tool for analysis in an information-based society. Conceptually, it deals with the cognitive skills of understanding data and using data to solve problems that involve traditional data bases of land use, soil types, and topography, and untraditional data bases of MRI and CAT SCAN images. (p. 17)

The use of GIS represented an excellent example of the use of technology to achieve goals of scientific literacy. As a part of the class activities described by Fazio and Keranen, students were challenged to use the data they had collected and analyzed to make decisions such as the placement of a landfill. Value-laden, community-connected investigations such as this were in the best traditions of scientific literacy and Science-Technology-Society (STS).

1.5 Creativity Tools

Computers as creativity tools were the third of Tinker's four categories for the use of computer technology. The use of computers as a means of fostering creativity provided students a means of expressing and enhancing their learning through the use of technology. By some measures, the Interactive Physics software qualified as a creativity tool, allowing students considerable flexibility and creativity in developing solutions to physics programs. More commonly used, however, were other sorts of creativity-enhancing software.

For elementary students, general presentation software provided much fodder for creativity. Etchison (1995) described her experiences using computers and software, presenting what a group of her students learned during a dinosaur unit of study.

> Students discussed various ways of communicating information, including newspapers, television programs, telephone calls, and letters, but they felt that none of these methods met their needs.... Faced with these problems, the class turned to me for help. Students told me what they wanted to do was to make a "dinosaur movie." I told them about *KID PIX Companion*, a computer program that could link their individual drawings together, creating a kind of slide show that could be seen *and* heard while it played continuously on the computer. (pp. 19-20)

Students then used this software to create a program describing what they had learned about the various dinosaurs. They researched questions relating to the life of dinosaurs and then were able to use the software to create their own dinosaur slides as part of the class's presentation on dinosaurs. The finished product was then shared with parents during an evening meeting.

Reflecting on the experiences of the students involved in this project, Etchison (1995) made the following comments:

> The dinosaur slide show was a high point of the evening for many parents. It was obvious to the adults that the finished presentation merely hinted at the amount of learning that had occurred during its creation. Students had learned to work with a partner and make joint decisions, had used sophisticated tools and equipment, and in a timely manner, had completed a project. The teacher, too, had learned from the activity. She discovered that her students were capable of handling a complex project, that they could handle the frustration of learning to draw a new way, that

> they could succeed at working "independently," and that they could use science process skills. (p. 21)

Working with another group of students in the same school, Etchison (1995) described the use of computer technology as students created a multimedia presentation on the topic of landforms, climate, and natural resources. The overall goals of the project were to find a way to seek out, secure, organize, and present their findings so that it could be shared with an audience of parents and classmates.

> By the end of the unit, students had learned a great deal about the various geographic regions of the United States....They had also acquired climatic data about each region, including each area's average temperatures (high and low) and amounts of precipitation. (Etchison, 1995, p. 30)

In addition to the specific content knowledge, students also learned to apply science process skills such as classification as they organized the information into the multimedia presentation. As a parent observing the project commented, "These are exactly the skills I require of my employees..." (Etchison, 1995, p. 30).

<u>Inspiration</u> represented another example of a tool with which creativity may be enhanced. <u>Inspiration</u> was software that allowed for the organization of symbols that helped students to think and learn visually.

> In Inspiration, you think and learn visually. Inspiration provides you with the tools that let you create a picture of your ideas or concepts on the form of a diagram. It also provides an integrated outlining environment for you to develop your ideas into organized written documents.
>
> When you work with visual representation of ideas, you easily see how one idea related to the others. Learning and thinking becomes active rather than passive. You discover where your deepest knowledge lies and where the gaps in your understanding are. (Inspiration Software, 1997, p. 13)

<u>Inspiration</u> was a graphic device that allowed students to arrange information on the computer screen, move it around to exploit the connections between concepts, and employ a tool in search for patterns. As a software application, it was designed to emphasize the development of higher order thinking skills and data analysis, which placed it firmly in the support of developing scientific literacy.

The use of the computer as a tool to enhance creativity offered fewer examples than other applications. This is perhaps due to the fact that, despite much interest in the higher purposes described by proponents of scientific literacy, science teaching tends to be more content-driven than an expression of creative endeavor. As more software is developed to help students tap into and express their creative urges in the disciplines of science, more examples will be forthcoming.

1.6 Communications Tools

> The educational implications of the Internet are promising....With carefully planned expansion, the Internet will empower teachers and students and will create a stronger link between school, home, and the world....The Internet has the capacity to serve as an equalizer, providing resources for all. (Gauger, 1994, p. 29)

The final category identified by Tinker (1987) focused on the use of the computer as a communications tool. "Word processors [and] telecommunications" (p. 468) are the two most commonly used communications applications for the computer.

By the late 1980s, the telecommunications applications available to public school students tended to be related to the use of computer bulletin board systems (BBS). This process allowed teachers to share and access resources on a remote computer through the use of a modem peripheral device. To assist science teachers, the Council of State Science Supervisors established "a national telecommunications network" (Gerlovich, Friedl, and Gillan, 1988, p. 42). The network made available curriculum guides, calendars, special projects and many other items of interest to science educators on a BBS.

In addition to serving the needs of educators, student interests were also served though the BBS. Students from Union Hill High School carried out an early investigation into this use of the computer with Scotch Plains-Fanwood High School, both located in the state of New Jersey. During the 1985-1986 school year, students from each of the schools participated in a network-based dialog on the topic of animal experimentation.

> With the topic settled, the project moved on to the research phase. Each student prepared a paper on an assigned subtopic, typed the paper into a computer file, and uploaded it to the EIES (New Jersey Institute of

> Technology's Electronic Information Exchange System) notebook. In this way, the students shared research and information obtained from outside sources. (Kenderdine, Hull, and Sirianni, 1988, p. 41)

Students then compiled the information they had amassed and combined it with additional input to the BBS. From these data, they completed a summary paper and uploaded their final statements to the EIES notebook. The work was then evaluated by a number of professional scientists with an interest in the topic of animal experimentation. Students in this project found that the professional review process was the most important part of the project in that it opened up their classroom to a world of practicing scientists (Kenderdine, Hull, and Sirianni, 1988). Consistent with contemporary views of scientific literacy, students were engaged in tasks not only connected to the practice of science but with societal ramifications on the role of animals (including human subjects) in scientific experimentation.

Similar uses of telecommunications were available as the development of the Internet received greater notice; several were examined in the section that follows.

1.6.1 Telecommunications: Using the World Wide Web (WWW)

Telecommunications was responsible for many of the overused clichés of the 1990s (the "information superhighway" was the primary offender) as well as an exciting tool for the science classroom. A number of applications for telecommunications were available by the middle 1990s: electronic bulletin boards, electronic mail, and the Internet. In the classification scheme that Tinker (1987) developed, he placed telecommunication in two categories: communications and information acquisition. His reasons for doing so were:

> Telecommunications appears twice in the table because it serves two distinct functions: gathering information from remote databases and remote acquisition sources and then sharing information through bulletin boards, conferences, and electronic publication. (p. 469)

This flexibility of telecommunications--as a means of sharing and then communicating information--offered many science educators of the 1990s a further incentive to infuse technology into their curriculum. Support for the use of telecommunications came from all levels, ranging from the grassroots "net days," in which parents, teachers, and community volunteers wired schools for Internet access, to stirrings in Congress supporting the intent

(though not necessarily the funding) of connecting all classrooms via telecommunications.

The pattern of hardware-pedagogy-software seen in previous technologies was present in a greatly accelerated sense with the infusion of telecommunications technology into science classrooms. Science methods texts such as Teaching Modern Science (Carin, 1997b) and Technology for the Teaching and Learning of Science (Reynolds and Barba, 1996) provided the entire range of documentation, from hardware through pedagogy and software in the space of one textbook chapter. The process was made somewhat easier than with the initial infusion of the computer into the classroom. In general, the hardware and some of the pedagogical issues related to using a computer in the classroom had been addressed during the previous decade. The challenges of teaching with a single computer were generally evaluated in terms of altering the class organization--using several work groups rather than whole class instruction.

Interest in the Internet was also very high among large numbers of teachers: the potential value of the technology helped to overcome reservations they may have had regarding the use of technology. The primary issues related to classroom use tended to revolve around whether the school had a single computer in the classroom or a designated lab for computer use.

A model program investigating the use of telecommunications technology as a tool for science learning, Project Storm Front, investigated these instructional issues. Two general trends emerged. The single computer in the classroom model made more generous use of direct instruction approaches to teaching; the computer lab model offered more opportunities for guided discovery learning (King and Thompson, 1998; Thompson and King, 1997). In either case, the focus of instruction was to promote the use of science process skill acquisition.

As regards software, the technology conceptually resembled the resources offered by a library. The computer ran software that accessed various web sites for the edification of teacher and students alike. The various web pages provided information in the form of text, graphics, audio, and video. The quality, however, was quite variable. Consistent with 1990s views of scientific literacy, the value of the experience, in large part, was in evaluating the quality and usefulness of the information obtained.

To aid in this process, many journals for educators published reviews of web sites. Fifty years after Brown (1939a) contributed reviews of films for science education in School Science and Mathematics, technology reviews (covering software and Internet web sites) graced the pages of School Science and Mathematics. The January 1998 issue, for instance, provided a briefly annotated list of web sites useful for investigating dinosaurs (McDonald, 1998).

As the use of the Internet entered more and more classrooms, the usefulness of the technology became more apparent. A lesson described by Butler, Flynn, Becker, and Zane (1996) was fairly typical of the use of the Internet as both a means of communication and as a rich data resource. In a series of lessons developed to support their school's earth science curriculum, the data analysis opportunities afforded by the Internet provided the essential content. To this end, a number of web sites with current and active earthquake information were identified, and students used this information to develop inferences regarding plate tectonics and related issues. The principles advocated in the 1990s conception of scientific literacy were present. Students were using information acquired through the World Wide Web as a means of testing hypotheses and constructing models and testing inferences.

1.6.1.1 Program Profile: Journey North

Journey North was a program developed and implemented during the middle 1990s as a means of exploiting the Internet as a tool to develop science process skill and content knowledge.

> The Annenberg/CPB Math and Science Project is pleased to present Journey North, an annual Internet-based learning adventure that engages students in a global study of wildlife migration and seasonal change. Beginning on Groundhog's Day (February 2nd) students will travel northward with spring as it sweeps across the continent of North America. With global classmates and state-of-the-art computer technology, they'll predict the arrival of spring from half a world away. (Educational Research Service, 1996, p. 32)

Students used the Internet as a tool to share, record and examine data in a number of ways. In particular, the focus was on creating an inquiry-based model of scientific investigation. In all ways, the development of the science process skills were present in each of the Journey North projects. Different activities occurred each year, but the intellectual activities remained similar from project to project. Data verification and testing, recognizing the value

of primary source information, and communicating information served as some of the key intellectual skills developed throughout the set of Journey North experiences (Journey North, 1998).

As a subset of the Internet, electronic mail was used as a communications medium to attempt to enhance scientific literacy. Several examples were drawn from the literature to demonstrate what was accomplished by the late 1990s.

1.6.1.2 Electronic Mail

Beyond simply gathering information from the Internet, many of the more interesting projects from a science education perspective exploited the communications capabilities of the Internet. Brienne and Goldman (1990) described simple applications with electronic mail:

> Few are the days spent reading and memorizing factual information from a single resource--the textbook--and writing answers to test questions for a single audience--the teacher. Innovative projects that tap into computer network technology and its capabilities are helping teachers lessen their reliance on the textbook, ushering in a generation of students able to think critically about science. (p. 26)

The critical thinking skills Brienne and Goldman (1990) spoke of were facilitated through the use of electronic mail communications. The use of science logs, shared through electronic communications, allowed for a wider range of individuals to be involved in the analysis of data collected during science investigations. As a means of gathering data, electronic mail was envisioned as an excellent tool.

> Electronic mail provides access to interview sources. For example, students writing research reports on earthquakes and volcanoes can send interview questions to students living in California and Hawaii. The interview data can then be incorporated into the report. (Brienne and Goldman, 1990, p. 29)

At the time of Brienne and Goldman's (1990) article, electronic mail had entered very few classrooms. Therefore, they addressed a number of issues related to what the technology looked like, how it could be used to facilitate learning in the science classroom, and examples of some projects which had successfully used e-mail in the classroom. What each of these projects had in common was the use of the technology to improve science communications and data analysis skills. Many of the principles described

in these early projects were used time and time again in other science projects that made use of electronic mail.

1.6.2 Interactive Multimedia

One trend associated with the use of the motion picture as a classroom technology was its gradual convergence with the videotape and television technologies. The issue of which technology was being used--the television or the motion picture--blurred its distinctions as they accomplished one and the same instructional goal by technologies that converged as a single tool.

In a similar fashion, the videodisc evolved to the point at which it became a peripheral tool associated with the computer, serving to unite several technologies into a single one. With interactive multimedia, the computer's software directed a set of video images drawn from a videodisc to be displayed, based on the needs of the student. Slowly, the once separate technologies of motion picture, television, and the computer became fused in a single multimedia package. Looking at the characteristics of the interactive multimedia approach, a number of technical advantages suggested themselves (Ross, 1991):

- high quality audio-visual characteristics
- high storage capacity (tens of thousands of still images can be accommodated on one disc)
- flexibility of makeup (each disc can store any combination of still frames, moving video sequences with soundtrack, and audio or digital data tracks)
- access to any individual frame within seconds
- long life (since there is no mechanical contact between the disc and the optical reading device, there is virtually no wear of the disc in use)
- versatility in interfacing (pp. 96-97)

A large body of research provided insights into the use of interactive multimedia in the science classroom. Some early notes on the use of interactive multimedia were offered by Lehman (1986) (see also Salpeter, [1986] and Howe, [1983]):

> One of the most promising innovations to burst on the educational scene in recent years represents the integration of computers and telecommunications; it is interactive video--a computer interfaced to a videodisc or videotape player....(Lehman, 1986, p. 24)

> Traditional forms of computer-based instruction--drill and practice, tutorial, and simulation--can be enhanced with interactive video. Instead of being restricted to the computer's often limited graphics and sound, the sound and clear visuals of the videodisc (or videotape) can be made an integral part of instruction....(Lehman, 1986, p. 27)

Early studies compared the use of interactive video with non-video instruction of the same material. Smith and Lehman (1988), summarizing the earliest body of research, found the interactive video groups had higher levels of achievement in a shorter amount of learning time than did subjects in the non-video control groups. Studies that focused primarily on science education offered similar results. Bunderson, Olsen, and Baillio (1981) undertook the study of interactive videodiscs as a tool for enhancing science instruction. Their findings supported the use of interactive videodisc instruction as part of the entire set of experiences for students in the science classroom. Students in their study,

> show significant increases in student ratings of knowledge and confidence in biology. The ratings of attention with the videodisc were also significantly greater than student ratings of attention in biology and their other...subjects. The videodisc is very effective in holding student attention. Students also feel very knowledgeable and confident about biology following a videodisc learning experience. (Bunderson, Olsen, and Baillio, 1981, p. 53)

Other studies confirmed these results. Findings from a study of the use of interactive video as a means of teaching the process and concept of titration to high school students, suggested that the interactive videodisc approach

> held their attention, maintained their interest, and provided a convenient format to input their simulated lab results. (Stevens, Zech, and Katkanant, 1987, p. 23)

In addition to the finding that the students' regard for the experience was very positive, the instructional advantage of offering students immediate and meaningful feedback was cited by nearly all of the participants as crucial to their positive regard for the experience. Controlling the rate of learning was also regarded as valuable to the students.

A number of schools infused interactive multimedia technology into their science programs. Hinerman (1991), <u>THE Journal</u> ("Laserdisc Technology", 1986), Kramer (1991), and others profiled their successes with interactive video laboratories.

Interactive video was also used to assist in the development of science concepts for earth science instruction. From the point of view of Rita ("Laserdisc Technology", 1986), the teacher who designed and taught the course, the use of interactive video offered great advantages in terms of student learning:

> We pick up the ones whose minds are usually travelling and get them to stop and think about what they're doing. And it's amazing how grades have gone up. After 23 years of teaching, I feel and I know that the interactive video has had an effect. (p. 54)

Her method of instruction was to use the interactive videodisc as a resource database. Henry created a story line by using authoring software and the images available on the videodiscs. Students, in collaborative teams, used these resources to develop an understanding of the structure of not only the solar system but also the entire earth science content. School Principal James Buckley, a strong advocate of the project, stated:

> I'm very pleased with what's going on...The videodisc application has allowed us to bridge the gap between students with different sorts of ability. In science, we get into some subjects and abstract concepts that are difficult for some students to grasp. With the interactive video, they can see the concepts and they're able to get it. ("Laserdisc Technology", 1986, p. 54)

Kramer (1991) echoed the experiences reported by Henry and Buckley. To promote the use of this technology, Kramer (1991) offered instruction in the use of an authoring program to create an interactive multimedia presentation. While it may have been the rare science teacher who would follow his example and author the course materials from the ground up, the larger point to be made was that the software to create interactive multimedia programs fell well within the skill base of most teachers.

By the 1990s, the need for teachers to individually author their own interactive video for classroom use declined. Litchfield (1990) recognized some of the difficulties related to infusing technology into the classroom and offered some perspective on integrating videodisc technology into the classroom. Her suggestions focused primarily on issues of instruction--changing and adapting the roles of the student and teacher to make use of this technology. First and foremost, she made this suggestion to restructure the classroom:

> The classroom structure needs to shift to a student-centered atmosphere. Existing curricula and classroom procedures can be adapted to give students choices in their learning sequence....Ideally, all science classrooms incorporate ...[learning] centers. But reality is such that the majority do not and will not for a myriad of reasons. This is why videodisc technology is such a boon to the science classroom. (Litchfield, 1990, pp. 17-18)

Other changes that needed to occur as the infusion of interactive multimedia technology continued were to extend the role of the teacher and students. Allowing for students to set, inasmuch as possible, their learning agenda and to have teachers teach to the needs of the students were two more considerations. The constructivists, with the desire to develop student learning among their interests, would applaud this aspect of technology impacting instructional practice. The flexibility inherent in the technology allowed these changes to take place, assuming a genuine desire to effect change was present. The final task was to use the technology as a tool to "provide opportunities and activities to develop higher-order thinking skills using the videodisc." (Litchfield, 1990, p. 21) Litchfield's (1990) article described anticipated best practice based on classroom trials with the material.

Other authors described classroom practice from the perspective of a science teacher. Hinerman (1991) described his classroom uses of interactive video labs in his high school biology classroom. To accomplish his ends, he made use of the Life Science Series from Optical Data and Cell Biology from Videodiscovery.

His rationale for using this interactive video approach was related to very traditional reasons for infusing technology into the science classroom:

> Too often, teachers will use the latest technology in a passive way, allowing the educational information to be dispersed at the teacher's pace and from his or her point of view. The use of the interactive video system in the environment, however, allows the student to view materials at his or her own pace in an objective manner.
>
> The interactive video system is multi-purpose: It provides opportunities for the student to view materials that could both be shown in the normal high school lab environment, it involves the student with the use of a computer and the videodisc technology, and it actively involves the student in the learning process. (Hinerman, 1991, p. 52)

The use of the interactive multimedia approach served several purposes. First and foremost, it allowed students access to a set of experiences that parallel those associated with a standard science lab. From an administrative point of view, it accomplished many of the same ends at a reduced overall cost, when the long-term cost per student for the technology is compared to the cost of purchasing live specimens and other expensive supplies.*

2. LINK TO SCIENTIFIC LITERACY

The computer provided another set of tools for science teachers and their goals of promoting scientific literacy among their students.

The 1990s perspective of scientific literacy, rooted in Hurd's 1958 essay on the subject, found that the use of the computer in the science classroom consistently supported the goals of scientific literacy. Software improvements allowed for many different applications, so computers have found service in activities ranging from developing content knowledge to developing more sophisticated science process skills.

As the computer's use in the classroom has been present since the 1960s, during the time of the NSF-funded curriculum movements many classroom applications of the computer were consistent with the scientific literacy perspective embraced by the 1990s. Early uses such as Papert described with LOGO represent the goal to use the computer as a means of developing thinking skills as much as teaching students the discrete content associated with programming in LOGO.

In addition, even some of the programming-based uses of the computer from the late 1960s focused on the use of the computer to develop (contemporary) notions of scientific literacy and an appreciation for the nature of science. Using the computer to collect large sets of data for analysis and to gain an appreciation for the role of uncertainty in measurement had important consequences for recognizing the process of scientific investigation and analysis.

* Similar issues were debated in the early 1930s as science educators were debating the merits of the laboratory experience with respect to science teaching. In the name of economy and efficiency, a number of high schools went exclusively toward demonstrations as a means of reducing costs and maintaining student performance. See DeBoer (1991), A History of Ideas in Science Education: Implications for Practice, pp. 111-112.

The comments of Kramer (1991) in his article on using and creating interactive multimedia learning presentations also fit into the larger issue of the needs for scientific literacy for all students.

> We need to consciously consider ways in which we might expand this [traditional linear method of teaching] to allow individual students to choose, based on their curiosity at the moment, which way he or she will move through a lesson. (p. 185)

This underscored at least two points of the 1990s conception of scientific literacy: teaching to all students--the "science for all Americans" idea--and teaching students in such a way as to find a better fit between the needs of the student and the needs of the curriculum. The National Science Education Standards (National Research Council, 1996) addressed this second point by encouraging "more emphasis on...selecting and adapting curriculum" (p. 52) as teaching practices were reconsidered.

3. REFLECTION ON CURRICULUM TRENDS

Reflecting on the place of the computer in science teaching, the pattern of hardware-pedagogy-software was evident once again. The use of telecommunications and interactive multimedia provided two additional examples of the pattern, in these instances a remarkably accelerated version of these events.

The focus on the hardware was evident in works such as DiSpezio (1989), Weiland (1990), Graef, (1983), and Moore and Moore (1977b). The implied message of delivering the science teacher and students into a new level of experience was implicit in the discussion. But the need to learn the hardware first provided much of the focus of the discussion. The articles on the use of peripheral devices were typical of this type of discussion, with teachers and students being encouraged to investigate phenomena ranging from temperature changes in Seivers (1986) to earthquakes by Averill (1995).

Developing appropriate pedagogy can be clearly seen in articles by Litchfield (1990), Fazio and Berenty (1983), and Wainwright and Gennaro (1984). Though some mention was made of the hardware needs to apply the teaching, the tacit assumption was that the hardware was no longer the issue, but rather that the determination of effective teaching strategies was preeminent. Litchfield (1990), in particular, discussed in detail the changes needed in classroom arrangements and instruction in order to make the most

effective use of technology. Fazio and Berenty (1983), it will be recalled, examined the use of team projects as a means of accomplishing instructional goals supported by the use of the computer. Wainwright and Gennaro (1984) offered insights gained from teaching practice to support the use of the computer in the classroom, particularly the use of a single computer for an entire class of students. In addition, they offered suggestions of some useful pieces of software designed to achieve the teacher's instructional goals.

Articles profiling and detailing the use of various software applications in support of science teaching evinced the third step in the evolution of technology in the science classroom. These ranged from capsule reviews (see Repak, 1988; Saiz and King, 1992; and Texley, 1990) to extensive pieces detailing comprehensive applications of technology in the classroom. Science and Children, to take one practitioners' journal, published monthly software reviews for teachers beginning in the middle 1980s. These reviews had the additional advantage of being written by practitioners in the field, so they offered some insights into the kinds of software which teachers found to be useful (Wulfson, 1993a; 1993b; 1993c).

Garner (1982), writing in Science and Children, profiled the process of selecting appropriate software, helping to empower early users of software to make the best and most economical decisions of where to spend classroom dollars. As an early proponent of using the computer in the classroom, he recognized that many users were still quite naive. The first category in software selection, "Is the Program Easy to Use?" stated: "A program should never assume that the user has experience with computers" (Garner, 1982, p. 24). This reflected the struggles with adopting some new technologies for classroom practice. Considering that so many of the articles appearing in National Science Teachers Association (NSTA) journals required both programming and hardware knowledge, that requirement would have served many potential innovators well had that standard also been applied to the article review process. Though many individuals with high levels of skills doubtless benefited, the required level of expertise doubtless dissuaded many interested parties.

The continued explosion in the growth of computer-related information led to the publication of more than simply articles outlining the hardware, pedagogy, and software associated with classroom uses of the computer. Lind (1984) offered an overview of journals supporting the use of technology in both the science classroom and in the regular classroom. Clearly, by the middle 1980s, the explosion of knowledge was difficult to

contend with. Additional help was offered in the form of a "Microcomputer Software Evaluation Instrument" published by the National Science Teachers Association (1984). The scales used for evaluation considered issues such as the accuracy of the content knowledge, fairly representing the pursuit of science and scientists, and the quality of the program in terms of both graphics and ease of operation. This feature proved to be quite popular; a streamlined version of the form was printed the following year as well (Reynolds, 1985).

Other assistance for science teachers hoping to make more effective use of the computer was provided by LaShier (1981). His overview of microcomputer journals relating their content to the needs of individual teachers helped to move the focus of the computer beyond simply an awareness of the hardware. It moved the discussion further into issues related to teaching and learning with computers, as well as alerting users to the increasing availability of software.

The computer also experienced the burden of extremely high expectations in terms of how it was to revolutionize science teaching. The title of Levin and Meister's (1985) policy report on the use of technology in the classroom--Educational Technology and Computers: Promises, Promises, Always Promises-- displayed both a little cynicism and a serious questioning of the role of technology in education.

From their perspective, they saw software as the key factor preventing the computer from taking a more prominent role in the classroom. As the market during the middle 1980s was somewhat small, though the need was large, they suggested a federal funding process by which software developers could draw funds to support research and development (Levin and Meister, 1985).

In the intervening years, market forces in tandem with the greater availability of hardware in classrooms have mitigated this sort of government intervention. However, up until the 1980s, the lack of "plug and play" software (i.e., software that could simply be turned on with a minimum of configuring before it was available for use) was a real barrier towards implementation.

With the increased availability of both hardware and software in the classroom--especially improvements in software--more teachers and students were able to make use of computer technology as part of the science class experience.

4. SUMMARY

This chapter examined the use of the computer in the science classroom. By examining the purposes served by the computer (as presented by Tinker, 1987)--as an instrument to acquire information, to analyze data, to offer creative expression, and to communicate with others--an appropriate organizational pattern was available.

The most common applications of the computer in science teaching were its use for simulation and information retrieval applications. Simulation software, available in both commercial and teacher-created varieties, provided an excellent means of developing science process skills and higher order thinking skills as a part of the student's interaction with the software.

Microcomputer-based Laboratories, though well represented in the science teaching literature, were challenging endeavors during their early incarnation. While it is certain that students would benefit from their use of the MBL, the requirements for the teacher's knowledge base were extreme; few teachers would be likely to use them due to the large amount of programming and hardware knowledge required.

The Internet and interactive video were among the most recent technology infusions into science teaching. Interactive multimedia provided a number of simulation and investigation experiences for students in the sciences, with the level of interactivity much higher than in previous types of simulations.

The Internet, both as a source of information and as a communications medium, found its way into larger and larger numbers of classrooms during the 1990s. Several initiatives engaged students in interactive learning with other students located across states, nations, and continents.

Scientific literacy issues were clearly supported by the use of the computer in the classroom. In particular, software that allowed students the chance to analyze and interpret data as well as empowering ever-larger groups of students to engage in scientific investigations promoted the best ideas of contemporary scientific literacy.

Finally, the pattern of hardware-pedagogy-software presented itself though any number of articles supporting the use of computer technology in the science classroom. As the development of hardware and software accelerated and the availability of computers in the home and school

expanded during the 1980s and 1990s, so too did the number of articles assisting teachers with the infusion of technology in the classroom. Nonetheless, the pattern of hardware-pedagogy-software dissemination remained intact.

Chapter 7

Perspective

Looking Back... and Looking Ahead

Having examined science education and technology through the course of the century, it is appropriate to place the use of technology in science teaching into a broader context and to consider other avenues for research into what the use of technology could bring to science education.

Technology has not necessarily produced radical innovations on the level of the teacherless classroom; rather, it has allowed some innovative activities to take place in individual science classrooms. Reports from science teachers have offered numerous practices that automated and innovated science instruction. Technology has been a tool for more effective instruction as teachers sought to achieve the evolving goals of scientific literacy.

1. SCIENTIFIC LITERACY

The view of scientific literacy underwent a number of transitions during the twentieth century. Though the term "scientific literacy" was first coined in 1958 and has come to represent a certain set of goals in the teaching of science, other science education goals have been present throughout the twentieth century. In the earlier part of the century, the primary consideration of what constituted scientific literacy related to the depth and scope of content knowledge by students. As the decades wore on, to the content knowledge was first added a set of thinking skills and then a recognition of the role of knowledge in a broader societal context. The acquisition of the thinking and content tools of science would allow the scientifically literate citizen to "engage intelligently in public discourse and

debate about matters of scientific and technological concern" (National Research Council, 1996, p. 13).

As various technologies have been used in support of teaching practice, they also reflected their times and the best thinking as to what constituted scientific literacy. The use of the motion picture and television, for example, was justified in terms of bringing the outside world to the classroom. Making a situation more authentic for a student and enhancing the student's level of understanding provided justification for the use of a technology that was consistent with the existing concept of scientific literacy.

By the early 1990s, the concept of scientific literacy had expanded to make science learning more inclusive for all students. Science for all Americans was not only a title of a document promoting scientific literacy, but it also served as a signal that anything less than universal scientific literacy was not to be tolerated. For example, current uses of the computer as a classroom tool helped to develop this theme in classroom practice. The computer helped to provide all students with access to information, thus providing an avenue for all students to achieve the goals of scientific literacy.

Scientific literacy has come to represent the goal of science teaching. The complete acceptance of this goal can be seen as numerous states have adopted similar goals for their own state learning standards. Illinois, to take one example, identified a number of broad goals consistent with the pursuit of scientific literacy, as well as specific classroom-level objectives that are consistent with scientific literacy objectives.

With similar goals adopted by the states and two national initiatives promoting the same general view of what represents scientific literacy, the broad notion of scientific literacy should remain intact for the foreseeable future. Barring another Nation at Risk type of document, with an emphasis on returning science education's focus exclusively to content, or a movement promoting the needs of an educated elite over the masses, the current conception of scientific literacy should take science education well into the next century.

The likelihood of a national curriculum of some form—including some goals related to that of scientific literacy—is strong. Both the Clinton administration and the American Federation of Teachers have endorsed such a proposal; the Clinton administration's goal of national testing could serve as a first step toward the adoption of national educational goals and an

attending curriculum. Arguments in favor of and against this approach exist, The perceived need for consistency in content and identifiable goals for learning lend support to the introduction of a national curriculum. Arguing against a national curriculum are advocates of local control of schools and supporters of allowing maximum freedom for teachers to teach to the needs of their students. This argument will likely continue whichever approach the future holds.

2. MOTION PICTURE

The use of the motion picture over the last nine decades underwent several transitions in classroom application.

In the early days of the motion picture in the science classroom, the focus was on two issues: efficiency and accuracy of content knowledge. Numerous studies attempted to teach students identical sets of content, with the experimental group experiencing film-based instruction and the control group exposed to more traditional methods of instruction. This, in principle, served to address both goals. Teaching larger groups of students and teaching with a minimum of teacher interaction served the purposes of efficiency. Teaching with film as a tool allowed for the content knowledge to be prepared by experts, increasing the accuracy of the content. This point connected strongly with the scientific literacy considerations of the early part of the century, when the increased quality of content knowledge among students was a critical issue.

As the decades wore on and use of the motion picture became more common, advances in hardware, such as videotape, allowed for some changes in practice to take place that helped teachers to achieve more sophisticated objectives.

In its current guise as videotape, the motion picture continues to serve as a helpful classroom tool. The convenience offered though the use of taping television broadcasts for classroom use has been popular with the current generation of teachers. As the availability of pre-recorded tapes continues to grow as it has over the last fifteen years, videotape technology will continue to find itself welcome in the classroom.

Film loops, to cite another example, allowed teachers to focus on single concepts during a 3-4 minute presentation. As they were available in a cartridge that could simply be plugged into a player, ease of operation was

very high indeed. Though soundless, they were helpful in focusing on relationships and changes such as helping students to comprehend the role of components in vector forces or the depletion of oxygen caused by a burning candle in a closed system. Their use has been absorbed by the videodisc, allowing essentially the same flexibility but in a more substantial format.

The videodisc provided another example of how improvements in hardware could be used to achieve educational goals. The extreme flexibility of the videodisc allowed for a greater degree of interactivity in its use in the classroom. As an interactive frog dissection, it helped students to focus on relationships between systems as well as on the identification of individual organs. For teachers, the traditional ability to bring the world into the classroom was supplemented by the capability of arranging the sequence of video images in any order desired. Uses for review and assessment, such as those outlined with the Britannica Science Essentials series, were also helpful for achieving goals of science literacy.

A potential change in the distribution system of motion pictures may be made through the Internet. As connection speeds increase and allow greater amounts of information to be more rapidly accessed by teachers and students, the means of accessing video information will likely be from central distribution centers. This idea is already in practice with the Folkways and Twin\Tone record companies; music is available for consumer download rather than traditional over-the-counter purchase. This allows each company to keep their entire music catalog "in print."

For video, the process would be similar, with teachers able to access desired video images from a central distribution facility. This is similar in concept to the "Education Utility" endorsed by Gooler (1986). This approach will be addressed in more detail shortly.

Digital video disc (DVD) technology is another area of critical interest, offering improvements and refinements in other aspects of the software and delivery system. Possessing the information storage capabilities of a twelve-inch videodisc, and much more, with the physical size of a CD-ROM, it leads to a number of areas of interest, in particular the development of interactive multimedia applications.

DVD was available by the late 1990s as a medium for commercial motion pictures, but the area of particular interest is its potential as an interactive learning tool. The DVD offers the ability to include as much as eight hours of video content on a disc only five inches in diameter, along

with eight audio tracks, and interactive hypertext capabilities (without the use of a separate computer). DVD will offer creative educators an excellent tool to share video images with students--and a challenge for the creators and developers of educational media to make use of DVD's potential.

3. RADIO

The radio led a relatively brief life as an instructional technology in the science classroom. This chapter examined the use of the radio in the science classroom from the 1920s through the 1940s. The two patterns of implementation were found to be common in science education. The approach used in Wisconsin exemplified a state level approach, in which instruction was developed and broadcast to serve the needs of the entire state. The school district of Rochester, New York developed a similar approach, but on a level that served the needs of a single district, and on occasion, the school surrounding the city of Rochester.

In both cases examined, significant improvements in student learning were achieved in classrooms that made use of the radio-based science lessons. By the end of the 1940s, however, science instruction using a broadcasting approach had moved from the radio studio to the television studio.

4. INSTRUCTIONAL TELEVISION

The development of instructional television for the science classroom has undergone a transition from capturing live broadcasts to making use of videotape to use broadcasts at the convenience of the instructor. This practice will likely continue. Also the transition from locally produced programming to programs produced at a regional or national level should also continue.

Instructional television, at the outset, offered a few key differences between itself and motion pictures. In particular, the ease of use for the technology and the ability to experience live broadcasts of some interest gave it immediacy not offered by the motion picture. As the decades have passed, the increasing use of prerecorded broadcasts has allowed the differences between the motion picture and the use of a television as a teaching tool to become minimal.

Likely to change will be the means of receiving information via television. As in the home, the shift to cable and satellite-distributed broadcasts will likely become more common in schools. This will allow for a greater variety of educational programming to be used in the classroom, and videotaping will allow the broadcasts--whatever the source--to be used at a time deemed appropriate by the instructor.

The Internet may also find service as a means of bringing television broadcasts into the classroom. With greater sophistication in technology and greater delivery speeds occurring on a regular basis, the use of telecommunications technology to serve as a means of distributing television broadcasts would seem to be a logical progression in the classroom use of the television. As the video feed technology and content of the Internet continue to improve, it is quite possible that within a few years, the Internet will resemble a television set with thousands of channels available.

The Internet as a potential television receiver leads to a consideration of what the future holds for the computer and what new practices may be anticipated.

5. COMPUTER

Reflecting on the place of the computer in science teaching, one was struck first by the similarity in the pattern of adoption seen with the motion picture and the television.

The initial fixation on the hardware followed by the development of teaching strategies to be used with the computer represented the first two steps in the infusion of the computer in science instruction. Finally, the application of software supporting instruction dominated much of the discussion pertaining to current computer use in the classroom.

A challenge facing future curriculum developers may relate to the flexibility inherent in some of the new technologies. It may be that the pattern of hardware-pedagogy-software may become a relic of a simpler, pre-digital age. Scripting DVD for learning situations has essentially no precedents. When used in conjunction with the computer, approaches to learning involving the interaction between the learner and software may place the creation of the software <u>before</u> the development of the most effective pedagogy. At the very least, a more iterative process in which the

movement ahead depends on the interaction among the pedagogy, software, and even the hardware would seem to be a conservative speculation.

An additional reflection on this continuum of how technology's use evolved in classroom practice related to individual differences within schools and within teachers. Though the theory and practices are well advanced, individual schools and teachers are located farther down on the continuum. How to accelerate this process and engage more teachers in the use of technology in their teaching remains a challenge.

Tinker (1987) described a number of conceptual uses for the computer. The categories he suggested--information acquisition, data analysis, creativity, and communications--all represent areas for growth in the use of the computer in the science classroom.

The area of information acquisition offers some exciting possibilities. As mentioned previously, the ability to transmit video images via the Internet is showing great improvements in both quality and download speed. Enormous amounts of data and text are already available via telecommunications; adding improved video and audio to the database are the next logical steps.

From this point of view, entire curricula could be accessed electronically. The Education Utility, mentioned previously, provided a framework for this approach:

> The Education Utility is an electronic delivery and management system that will provide instantly, to the desks of educators and students located anywhere in the world, massive quantities of continually updated instructionally interactive information (software programs, databases, sophisticated graphics capabilities, news services, electronic journals, electronic mail, and other instructional and administrative materials). All of these materials will be stored or accessed through a main "host" computer. Individual educational sites...will be connected via a state network. (Gooler, 1986, pp. 11-12)

Through this Utility, individualized instruction, group work, and large group instruction could be organized electronically. This sort of approach would be well-served by a national curriculum, as the Education Utility would be ideally situated to operate as a delivery and management system. The philosophical issue as to how this would impact student and teacher autonomy remains to be decided. It is worth considering also that the Education Utility described by Gooler was more than simply a theoretical

construct; it described an actual working program. That it was developed a decade before the common use of the Internet suggests that it was a sound approach, but the lack of supporting technology and software prevented it from becoming a historical curiosity as well as a model for delivering instruction.

6. ANTICIPATION OF FUTURE TRENDS

Trends for the use of technology are difficult to predict. From the vantage point of a generation ago, some predicted that all teaching would have been taken over by machines in the name of both efficiency and effectiveness. What has transpired has been the use of technology to help students and teacher manage, present, and communicate information. The machine as teacher has appeared in some small ways, but the teacher using a machine is quite commonplace.

The greatest concern that can be expressed for science teaching is that the hands-on/minds-on experience should remain preeminent. Technology represents an important tool for effective teaching, but the heart of the science program should be developed around student inquiry with materials. Technology is best suited for extending and deepening the level of investigation and understanding, but not as a substitute for the activity.

Anticipated changes will take place in two areas. The first includes the issues discussed in this study--the hardware, pedagogy, and software associated with using technology in the teaching of science. This will allow students and teachers to gain more information, to manage their information more effectively, and to communicate between and among students and classrooms beyond a single room. Hurd (1997) summarized the advantages of technology in science education:

> The transformation of our powers of observation and the technology for the management of data emphasizes that the practice of science comprises both theory and craft....We can expect more changes in the practice of science as the "information superhighway" develops and makes it possible to locate and access all the knowledge ever produced in the sciences. (Hurd, 1997, p. 55)

The other area relates to educational policy. The Education Utility represents a vision that would require a serious realignment of the organization of the classroom, school, and school district. The Goals 2000 initiatives represent another policy issue that may potentially impact the way

science teaching is carried out. Technology can ideally serve as a tool of democracy and empowerment, so long as all students have access to its resources. A worst case scenario would allow the current disparity in educational funding to continue in its present manner. This in effect would deprive students from impoverished school districts of access to technology.

This problem of disparity could be exacerbated if commercial publishers offer high quality (and expensive) curricula via the Internet. Technology-rich districts could access the finest curricula available, ultimately leaving other districts poorer in the technology and knowledge available.

Other changes in technology hardware are worth noting; among them are the further development of DVD and improvements associated with the information delivering potential of the Internet.

Current difficulties accessing information are related to slow download times or overloaded servers. As these difficulties are addressed and more useful information is made available electronically, the use of the Internet should continue unabated. Further, as the ease with which students may publish on the Internet increases, the potential to raise the use of the computer to a communications medium rather than an information retrieval medium is enhanced. Higher levels of interaction among students are generally associated with higher levels of engagement and higher levels of learning.

A consequence of the computer serving as a means of accessing information encoded on a DVD is the further blurring of the boundaries between the technologies examined in this study. As the computer itself becomes a single device that can deliver motion pictures, broadcast television programs, and operate a wide variety of software, the various technologies examined here become separate but related applications in a single device. When the additional communications and information acquisition potential of the Internet are included as well, the computer has even greater potential to serve as a highly sophisticated educational tool--the Education Utility, indeed.

7. SUGGESTIONS FOR FUTURE INVESTIGATIONS

A general statement regarding the use of technology in the classroom may be derived from Salomon and Gardner (1986). The focus of their

article was to provide a caveat for those technology enthusiasts who would recklessly infuse the computer into classroom practice before sufficiently informed pedagogy was developed. Learning from the struggles of advocates of instructional television, they made the point that educators must

> realize that learners bring many assumptions, proclivities, and active learning strategies to any encounter with a new medium or technology; and...[to] expect a range of usages and experiences and a variety of outcomes from any encounter between an individual and a computer. It is particularly important to carry out background research before computers become completely pervasive in the educational environment. (Salomon and Gardner, 1986, p. 13)

It is now fifteen years later and too late for the background research to be carried out. The computer is present in many classrooms and serves primarily an ornamental function. The suggestion to be made here is that as we prepare to welcome new technologies into the classroom, the initial baseline data we collect can be of invaluable help during later efforts at infusion into instruction.

An investigation into the use of technology informed by social psychology--particularly the use of expectation-value theory--can provide further insights into teachers' uses of technology. From the perspective of expectation-value theory, individuals engage in certain behaviors based on two factors: the value they attribute to engaging in the behavior and the expectation they have for success. Technology, with its promise of serving as an effective tool for teaching coupled with the challenge of requiring new skills of its user, would be well served by a critical examination of the relative weight applied to these two factors.

An additional area warranting further investigation based on classroom observations is actual teacher practices. Actual classroom practice often departs greatly from what is reported on surveys and other forms of teaching inquiry. Time spent observing the actual classroom practices associated with the use of technology in science teaching could be most revealing. Findings from this body of investigation might well be applicable to both preservice and inservice education as teachers evaluate the benefits of using technology when weighed against the costs involved in its infusion.

An investigation into classroom uses of technology in other fields would also be of interest. Rather than examining the use of technology in the context of scientific literacy, as was done here, examining the use of technology from the point of view of the dominant theories from educational

psychology could prove to be most illuminating. How the dominant behavioral perspective from early in the century impacted the use of technology compared with the cognitive orientation present today would be highly engaging and illuminating.

A critical element missing in many instances is the modeling needed in colleges of education. The role of modeling has been well documented in the teacher education literature. Until such time as colleges of education promote the use of technology by modeling its use in all methods courses and requiring its use by preservice teachers, it is likely to remain a seldom-used tool.

And finally, the literature would be well served by an extension of the heart of this study into the next century. A continued and detailed accounting of the use of technology to achieve scientific literacy into the next century will provide a depth and scope of detail as to science teacher practice with the use of technology.

8. FINAL REFLECTION

At the outset of this study, the author would have predicted that numerous teachers would infuse technology simply for the sake of using technology. In essence, it was anticipated that the technology itself would provide a driving force for the infusion of technology into instruction. The technologies examined related a different story. Technology was more often than not implemented to achieve a particular instructional end—such as achieving scientific literacy—and not to promote the use of technology for its own sake. A typical article cited the advantages of using technology to assist teachers as either an "extra set of hands" or as a means of helping to develop science process skills and higher order thinking skills. The connection between the goals of scientific literacy and the potential that technology has offered to achieve that end has been consistent. Technology has provided such a tool for achieving scientific literacy.

The use of technology in science education underscores the need for a strong and coherent curriculum. Technology can serve as an excellent tool in the pursuit of scientific literacy, regardless of the device.

Another challenge of this study was from the nature of the reports on the use of technology. Consulting practitioner journals such as <u>the Science Teacher</u> informed the study by revealing actual practices, but the potentially

less useful applications of technology in science teaching—showing a video without commentary to simply use up a class period—are unsurprisingly missing from the literature.

The recognition that most uses of technology are devoted to automating instruction rather than innovating instruction is a point worth making. Most practices, particularly related to the use of the computer, had an antecedent that did not make use of the computer. Dissections, communication, accessing information, and many other practices were common experiences in the classroom. Technology allowed these activities to occur with greater efficiency in some instances and opened up opportunities to students that would not otherwise have existed.

Another trend with technology use has been the movement away from the view of teaching the entire lesson--viewing technology as a substitute for the teacher--to using the technology in only certain capacities. Though many educators in the early part of the century would have advocated the efficiency of a teacherless classroom--with all instruction offered by motion picture--this approach never really became common. Most examples from the literature described practices that attempted to do this, but the review of the literature did not reveal many instances of this becoming standard instructional practice. In essence, selecting the best tool for the task has become the common practice. Science fiction dreams of teacherless classrooms remain a fiction rooted in the past.

Another issue to consider regarding the use of technology in the classroom relates to student access. Democratic issues regarding access to technology for all students are a real concern. For all students to experience the advantages of technology, more equitable funding practices need to be implemented for American schools. As long as poor urban schools have to "ration crayons, pencils [and] writing paper" (Kozol, 1991, p. 64) technological equality is chimeral at best.

The final word: good teachers use a variety of tools. Technology represents one of the most important and effective tools available to a classroom teacher. In all of its manifestations, technology represents a dynamic and engaging tool which teachers may use to elevate their students' understanding and appreciation of the goals of scientific literacy, now and in the future.

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